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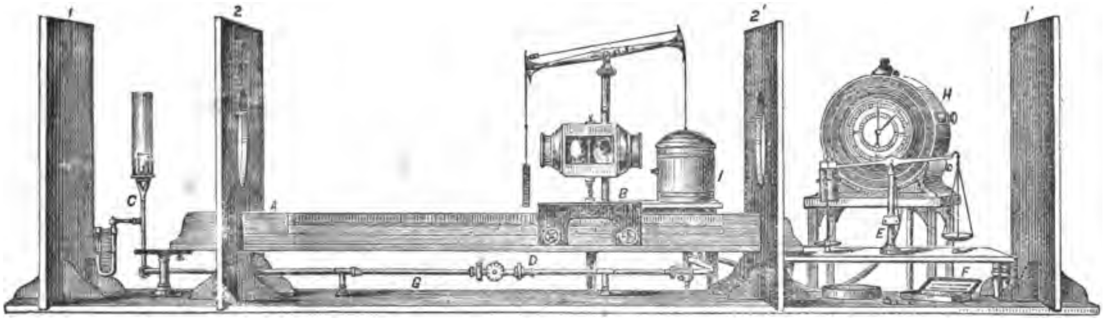
THE GAS ANALYST'S MANUAL.

F. W. HARTLEY



STANDARD LETHEBY-BUNSEN PHOTOMETER.

Schedule A, Part I., " Gas-Works Clauses Amendment Act, 1871."

(See page 13.*)*

THE

GAS ANALYST'S

MANUAL.

THE
GAS ANALYST'S
MANUAL.

BY

F. W. HARTLEY,

A.I.C.E., M.S.E., &c.,

HON. MEM. BRITISH ASSOCIATION GAS MANAGERS.

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PREFACE.

My desire in writing and compiling the matter of this book was, to produce a Manual which would be instructive to those who wish to learn, and useful to those who, already familiar with the Analysis of Coal Gas, may require at times to refresh their memories upon certain points.

The experienced Analyst may deem the Manual, in some particulars, unnecessarily diffuse; but such will not, I venture to hope, be the case with those who are unfamiliar, or but partially familiar with gas testings.

While dealing, necessarily, with scientific facts and processes, I have endeavoured, as far as possible, to give the work more of a practical than a scientific character, by formulating the principles involved in the shape of rules.

I have explained, as clearly as my ability would permit, the processes by which gas is tested under the operation of certain Acts of Parliament, and also described certain other processes which are of value to the Gasmaker.

I have freely incorporated all the essential points in the Instructions issued by the Referees of London, and also such other matter from various sources as I thought would be useful, but have not, in every instance, deemed it needful to indicate such incorporated matter by inverted commas or by acknowledgment.

My sincere thanks are due to several gentlemen of eminence for kindly hints and advice; of these I may specially mention—CHARLES HEISCH, Esq., W. VALENTIN, Esq., and A. VERNON HARCOURT, Esq.

F. W. HARTLEY.

London, 1879.

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ERRATA.—Page 70, par. 115, 3rd line, for "15" read "25"
,, 88, last line but one, for "poured in the crucible" read "poured into the pan, the crucible" &c.,
,, 101, top line, for 630·39, read 629·14
,, ,, ·36408 ,, ·3646
,, 4th line, ·0015863 ,, ·0015878
,, Par. 173, ·15863 ,, ·15878
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SECTION I.

PHOTOMETRY.

1.—PHOTOMETRY is the art whereby the relative illuminating power of artificial lights is determined.

2.—Practical Photometry depends, firstly, on the sensibility of the visual organs, and on the mental power to judge, under favourable conditions, respecting the equal illumination of an object; and, secondly, on the law that the intensity of illumination is proportional *inversely* to the square of the distance of the object from the source of light.

3.—Many photometers have been invented, but in England those only which are based upon Bunsen's method of ascertaining the relative value of artificial lights have been generally employed. Bunsen invented and employed a screen or disc of paper, greased over part of its surface so as to render it unequally translucent. The disc was supported or held in an upright position, and the lights to be contrasted were placed one on each side of, but at some distance from, the disc, but in such manner that a straight line, if extended from light to light, would pass through the disc at right angles to its surfaces, and also through each flame midway between its apex and base. The weakest light was then moved towards the disc until the latter became equally illuminated on each side, when, as a consequence, the inequality in the translucency of its parts became invisible or nearly so, owing to the fact that in a position in which both sides are equally illuminated, the quantity of light transmitted through the disc in each direction, and the quantity reflected from its surfaces, are equal.

4.—The distance from the disc to the centre of each light was then measured and squared, and the quotient which resulted from the division of one of the squares by the other gave the relative illuminating power of the flames. Generally the value of the greatest light is expressed in terms of the weakest, the latter being regarded as the unit. If, for example, one of the lights were 10 ins. and the other 50 ins. from the disc, the squares of these numbers are 100 and 2500, and the latter divided by the former would give the value of the greatest as 25 times that of the weakest light.

5.—Many refinements have been made on Bunsen's method of using the disc, and probably in the disc itself, for the purpose of rendering the comparison of artificial lights as facile and exact an operation as possible. The most obvious of these consist in the employment of a graduated bar of specific length, the *fixing* of the lights, one at each end of the bar, and the placing of the disc within a box, open at its two ends and in front, which box is provided internally with two reflectors, set at such an angle as to present reflections of the sides of the disc to the observer's eyes, and is carried on a slide which rests upon the bar, and may be freely moved between the lights. The graduations on the bar indicate, on inspection, the value of the strongest light in multiples of the weakest, thereby saving trouble, and preventing the possibility of errors which might, in the absence of such graduations, arise from inaccuracy in measurements and in calculations.

6.—The fixing of the lights conduces to regularity of combustion and to steadiness of the flames, which are likely to be prejudiced by motion. Other, and possibly not less important, refinements have been introduced; the value of these may be understood from what follows.

The Purposes of Photometry.

7.—Photometry is practised for several purposes, viz., to ascertain the relative value of various substances used in artificial illumination, and the most advantageous methods of burning them; as a means of selecting burners which are suited for evolving the greatest effect from any illuminating gas, and as an aid to the improvement of burners themselves, etc.; but the purpose for which photometry is most extensively practised, is to discover whether the coal-gas supplied by Gas Companies is of such quality, in respect to illuminating power, when burned under fixed conditions, as the Companies are bound, either by special or general acts of Parliament, to furnish. It is to the last-mentioned application that the reader's attention will be particularly directed in the following pages.

Standard Light.

8.—The light adopted in the United Kingdom, under the authority of the Legislature, and also in the Colonies, as a standard whereby to estimate and express the illuminating value of coal-gas, is that which is derived from a sperm candle burning at the rate of two grains of sperm per minute, or, as usually specified, "sperm candles of six to the pound, each "burning 120 grains an hour." Few candles burn at this exact rate, and, in practice, "if the rate of con-"sumption per candle shall not have exceeded 126 "grains per hour, or fallen short of 114 grains per "hour," corrections by calculation are made for such variations from the standard rate. The Candle Standard is by no means a perfect one, but, in spite of its defects, it has many advocates. It certainly is a most convenient standard by which to express the value of gas; it can be used with greater facility than any other standard which has yet been put prominently forward, and when due care is exercised, and a sufficient number of experiments made on each occasion, the operator may arrive at results sufficiently accurate for all practical purposes.

Standard Burner.

9.—Anterior to about the year 1860, the descriptions which were inserted in acts of Parliament of the burners to be used in testing were most unsatisfactory, it being deemed sufficient to specify that the burner employed for common gas should be "an Argand "burner having 15 holes, and a 7-inch chimney." As a consequence, burners differing widely in their dimensions, in the proportion of their parts, and in their capability to develop the light power of the gas, were employed. The necessity for defining the burner was at last recognised, and attempts were made to do so, but not always with success, as witness the following description of a 15-hole Argand, extracted from the "Birmingham and Staffordshire Gas Act, 1864":—

"A metal Argand burner having an external dia- "meter of 1·10 inch, and an internal diameter of 0·50 "of an inch, and having fifteen holes, each hole of "the diameter of 0·05 of an inch, and with a 7-inch "chimney supported upon an ordinary gallery without "perforated disc."

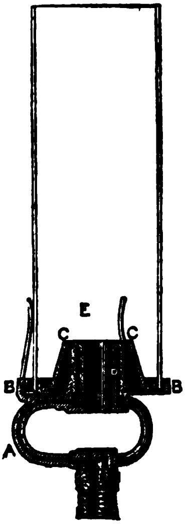
10.—The above-mentioned burner proved to be a very indifferent one, and the description is defective in several particulars, which, however, it is needless to discuss, as the 15-hole burners now generally employed are either of the Sugg-Letheby model or the 15-hole London Burner, the latter being similar, except as to the number of its holes, to the "Stan- "dard burner deposited with the Warden of the Stan- "dards [Board of Trade], in accordance with Section

"37 of the Gas-Light and Coke Company's Act, 1876" —the description of which, as well as of the flat-flame burner used with cannel gas in London, is given as follows in the Notification of the Gas Referees of London:—

"The burner which has been adopted as the standard "burner for testing common gas was designed by Mr. "Sugg, and was called by him 'Sugg's London Argand, "'No. 1.'"

"A full-sized section [*reduced for this book*] is appended, "in which A represents a supply pipe, B the gallery, C "the cone, D the steatite chamber, E the chimney.

"The following are the dimensions of those parts of the "burner upon which its action depends":—



	Inch.
Diameter of supply pipes -	0·08
External diameter of annular steatite chamher - - -	0·84
Internal diameter of do. - -	0·48
Number of holes - - -	24
Diameter of each hole - -	0·045
Internal diameter of cone:	
At the bottom - - -	1·5
At the top - - -	1·08
Height of upper surface of cone and of steatite chamber above floor of gallery - - -	0·75
Height of glass chimney -	6
Internal diameter of chimney *	1$\frac{7}{8}$

The standard burner for testing cannel gas is a steatite batswing burner, consisting of a cylindrical stem, the top of which is divided by a slit of uniform width.

	Inch.
External diameter of top of stem	0·31
Internal diameter of stem -	0·17
Width of slit - - -	0·02
Depth of slit - - -	0·15

---

* The maker provides each burner with a second chimney, which is also 6 ins. in height, but 1$\frac{5}{8}$ ins. only internal diameter. The smaller chimney is required with gas below 16 candles illuminating power.

11.—Many Gas Companies are still in an unfortunate position under the clauses of their acts of Parliament and of those of the Gas Works Clauses Act Amendment Act, 1871—the Schedule A of which recites that "the burner to be used for testing shall "be such as shall be prescribed." In justice to such Companies, the "prescribed" burner ought in every instance to be the same as that used in London, so that the true relative value of the gas they supply to that supplied in the metropolis could be known, and thereby the publication of any statements as to apparent inferiority in quality, which may be due to the burner and not to the gas, be avoided. Pending the possible further amendment of the Gasworks Clauses Act, Companies, especially those which are prejudicially affected, would do well to urge upon their consumers the employment of good burners, and thereby smooth the way in the proper direction.

GASWORKS CLAUSES ACT AMENDMENT ACT, 1871.

SCHEDULE A.

Part I.

Regulations in respect of testing apparatus.

12.—(1) *The apparatus for testing the illuminating power of the gas* shall consist of the improved form of Bunsen's photometer, known as Letheby's open 60-inch photometer, or Evans' enclosed 100-inch photometer, together with a proper meter, minute clock, governor, pressure gauge, and balance.

The burner to be used for testing the gas shall be such as shall be prescribed.

The candles used for testing the gas shall be sperm candles of six to the pound, and two candles shall be used together.

(2) *The apparatus*—

(*a*) *For testing the presence in the gas of sulphuretted hydrogen.*—A glass vessel containing a strip of bibulous paper moistened with a solution of acetate of lead, containing sixty grains of crystallised acetate of lead dissolved in one fluid ounce of water.

Part II.

Rules as to mode of testing gas.

(I.)—*Mode of testing for illuminating power.*

The gas in the photometer is to be lighted at least fifteen minutes before the testings begin, and it is to be kept continuously burning from the beginning to the end of the tests.

Each testing shall include ten observations of the photometer made at intervals of a minute.

The consumption of the gas is to be carefully adjusted to five cubic feet per hour.

The candles are to be lighted at least ten minutes before beginning each testing, so as to arrive at their normal rate of burning, which is shown when the wick is slightly bent and the tip glowing. The standard rate of consumption for the candles shall be 120 grains each per hour. Before and after making each set of ten observations of the photometer, the gas examiner shall weigh the candles, and if the combustion shall have been more or less per candle than 120 grains per hour, he shall make and record the calculations requisite to neutralise the effects of this difference.

The average of each set of ten observations is to be taken as representing the illuminating power of that testing.

(II.)—*Mode of testing.*

(*a*) *For sulphuretted hydrogen.*—The gas shall be passed through the glass vessel containing the strip of bibulous paper moistened with the solution of acetate of lead for a period of three minutes, or such longer period as may be prescribed; and if any discolouration of the test paper is found to have taken place, this is to be held conclusive as to the presence of sulphuretted hydrogen in the gas.

13.—The foregoing are the regulations and rules which apply to the whole of the Kingdom, inclusive of London; for, although the Referees in their Notification somewhat amplify them, the rules for testing remain practically the same as above given, with one exception, viz., that the Referees direct that corrections shall be made for barometric pressure and temperature, and this ought certainly to be done in all cases. The method of making such correction will be explained in the proper place.

14.—The propriety of so correcting the indicated illuminating power of the gas will be realised when it is remembered that gases (and vapours) are, in this country, assumed to be of *normal bulk*, and therefore to possess their *normal density*, when under an atmospheric pressure of 30 ins. barometer, and at a temperature of 60° Fahrenheit. It is true that in scientific investigations philosophers now generally assume that gases are of standard volume under a pressure of 760 millimètres (29·92 inches), and at the temperature of zero centigrade (32° Fahr.), but at 30 ins. and 60° Fahr., gases are at their average density in this country, and therefore corrections of volume to that pressure and temperature are justly made in gas testing, which is really a determination of its commercial value.

15.—Now, under an atmospheric pressure *below* 30 ins. or at a temperature *above* 60° Fahr., any gas or vapour is *below* its normal density, and in the case of illuminating gas, any measured volume contains *less* than the normal weight of illuminating matter. With a pressure above 30 ins. or temperature *below* 60° Fahr., the reverse effect results, and any measured volume would contain *more* than the normal weight of illuminating matter. Sometimes it happens, although rarely, that a rise or fall in pressure may be accompanied by such a rise or fall in temperature that the standard density is maintained; thus, at 30·8 inches and 70° this is the case, as it is also at 29·7 inches and 56°, as will be seen in Table C of the Appendix.

16.—The importance of the correction herein mentioned is best realised by an extreme illustration. Suppose, then, that gas were adjusted to burn at the five cubic feet rate, when the barometer was at 28 inches and the temperature 84°, the Table shows that the measured volume is only the 870-1000ths of the normal volume, or 4·35 instead of 5 cubic feet.

Description of Standard Apparatus.

17.—The apparatus which will be herein-described, as conforming with the requirements of the Gas Works Clauses Act (12) consists of the instruments named below :—

THE LETHEBY-BUNSEN PHOTOMETER,
,, CANDLE BALANCE,
,, EXPERIMENTAL METER,
,, MINUTE CLOCK,
,, EXPERIMENTAL GOVERNOR,
,, PRESSURE GAUGE.
,, BURNER,
,, SPERM CANDLES,
,, BUNSEN DISCS,
,, GLASS VESSEL OR SULPHURETTED HYDROGEN TEST,

all of which are absolutely essential; but to render the apparatus complete the following are also required:—

A GOVERNOR FOR THE SERVICE PIPE,
A GOOD BAROMETER.

18.—THE LETHEBY PHOTOMETER is shown in the frontispiece. A is the graduated bar, which is of such length that the centres of the flames to be contrasted shall be 60 inches apart, the positions of the flames being fixed (5). The bar is of polished wood, and it is graduated each way from its centre into spaces, numbered one, two, three, and upwards, to the ends of the two scales thus produced. The centre line, numbered one or unity, indicates the position at which the disc (3) would be equally illuminated on both of its sides, if the contrasted lights at the ends of the bar were of equal power, and two, three, &c., the positions for the disc, if the strongest light were two, three, or more times greater in light-giving power than the weakest (4).

19.—The numbered divisions (units) up to the ninth are subdivided into tenths, thence into halves up to 20, and from that point completed by entire units of indicative value.

20.—The slide B is provided with brass rollers in order that it may travel easily and smoothly on the bar, and carries a greatly improved disc-box, which is fitted internally with a disc-holder and with two reflectors (5). C is the gas-pillar fixed to the short standard which supports one end of the bar. From the pillar extends a horizontal pipe, which is provided with a stop-cock below the point A, and with a micrometer cock at D. 1, 1′ are upright black wooden screens, and 2, 2′ are similar screens, with central holes, through which the rays of light pass from the flames to the disc. G is a base board upon which the photometer and candle balance are fixed.

21.—THE CANDLE BALANCE. This is a very sensitive and accurate instrument, capable, if properly used, of weighing to the fiftieth of a grain. In the arrangement shown, which was devised by the Author some years ago, the balance E is attached to the photometer bar. The end of the beam nearest to the disc-box carries a holder for two candles, so that the candles may be weighed while in position for use and while actually burning. The operator is thus enabled to burn the candles under conditions most favourable to regularity of combustion, and also to weigh them with great exactness.

22.—The Experimental Meter. The dial of this meter has three divided circles aud two pointers, the short pointer, indicating on the *inner* circle only, and the long pointer, both on the *intermediate* and on the *outer* circles (fig. 2).

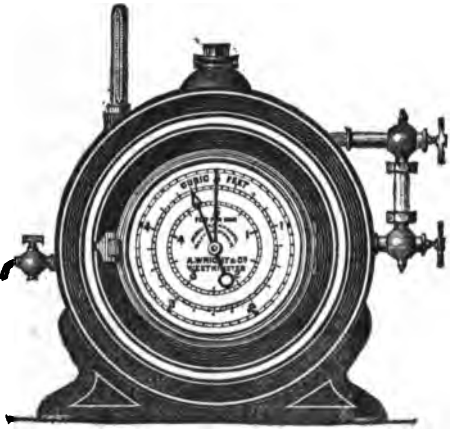


Fig 2.

23.—A complete revolution of the short pointer indicates the passage and measurement of 1-12th of a cubic foot of gas, or the quantity which must be burned in one *minute* in order to secure the standard rate of five cubic gas per hour. The centre circle is divided into *five* principal divisions, and as each of these represents 1-5th of 1-12th of a cubic foot or 1-60th of a cubic foot, it follows that the quantity of gas indicated by the passage of the pointer from one division to the next, bears the same ratio to a cubic foot of gas that one minute does to *one* hour. The subdivisions, of course, bear the same ratio to *tenths* of a cubic foot.

24.—The intermediate circle is divided so as to show the number of revolutions made by the pointer of the centre circle, *i.e,* each small division of the intermediate circle indicates a quantity equal to that of the entire ring of the centre circle, namely, 1-12th of a cubic foot. If, therefore, the long pointer passes from one division to the next in one minute, the passage of gas at the rate of five cubic feet per hour is shown.

25.—Taking *one minute* as representing, or as equivalent, in testing operations, to an *hour*, each principal division on the centre circle may be, and is called, one cubic foot, and each division on the intermediate circle *five* cubic feet.

26.—Hence, if the meter were started with the pointers upright, and therefore at zero, and at the end of 10 minutes the long pointer were found at 9 on intermediate and the small one at 4·5 on centre circle,

then 9 × 5 = 45·0
Add . . 4·5

Divide by minutes . 10)49·5
4·95 cubic feet per hour.

But the short pointer ought in the time named to complete ten revolutions and reach the zero, while the long pointer should cover the tenth division on the intermediate circle. Hence, in the illustration, the consumption is in deficit.

27.—Again, suppose at the end of *ten* minutes the long pointer were at 10 and the short one at 3·4,

then 10 × 5	=	50
Add	. .	3·4
Divide by minutes	.	10)53·4

5·34 cubic feet per hour.

In this example the rate of burning is in excess.

28.—The outer circle indicates actual cubic feet and tenths, and is not used in photometry, but for other purposes to which an experimental meter may be applied.

29.—The meter (shown at H in the frontispiece) must stand perfectly level, and be charged with water until the lower part of the meniscus, or cup formed by the water within the gauge at the side of the meter fig. 2, coincides with the line marked on the glass tube. Or if the meter be provided with a drip-socket on its side instead of a water-line gauge, it must be allowed to rest until the excess water is completely drained off. The socket is to be closed by inserting the screw plug. This, of course, must be done when the gas is off and the meter open to the atmosphere. The small hand may be freely moved backwards, and the pointers thereby set at zero when desired.

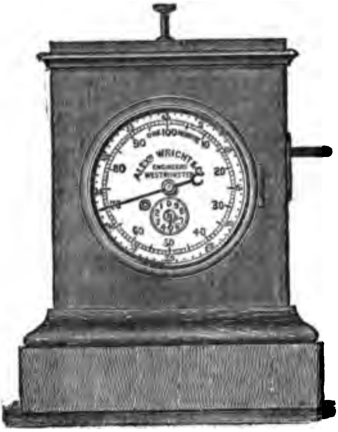


Fig 3.

30.—The Minute Clock. The most convenient form of clock is that represented in Fig 3. The circumference of the dial is divided into seconds, and also into 100 divisions, so that part of a minute may be read off to the second decimal place. It is furnished with a stopping and starting lever at the side, and with a press button at the top, by which the hands may be instantly set at zero, *i. e.*, upright. The small dial indicates 10 minutes, which is the time occupied in each set of photometric observations. Finally, each completed revolution of the long pointer, and therefore the passage of one minute, is notified by the striking of a bell within the clock case. Sometimes a long pendulum clock, such as is described in paragraph 85, is used instead of the foregoing, but is not so convenient.

31.—The Governor. The construction of a gas governor and the principle of its action are so well known, that it will suffice to say that the only peculiarity which the experimental governor possesses is extreme sensitiveness in action. The largest or central pipe is the inlet, the other pipe being, of course, the outlet for the gas. It is mounted on a table, the inlet and outlet pipes being between the legs, each pipe terminating with a small cock, by opening which water may be drained off, if from any accident it should get into the pipes. A convenient position for the governor is that shown at I in the frontispiece. The tank must be charged with water to the height of the side plug, when the pipes are open to the atmosphere and the gas shut off.

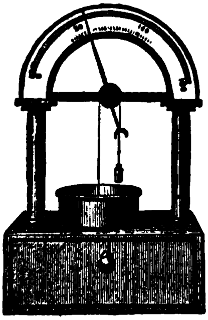


Fig. 4.

32.—The Pressure Gauge. A small syphon gauge, such as is shown on the gas pillar C of frontispiece, may satisfy the letter of the law, but the advantages attendant upon the employment of a King's gauge, such as is shown in fig. 4, are so great, that the latter gauge ought always to form part of a set of photometric instruments. The gauge may be placed in any convenient position on the photometer table—for instance, behind the gas-pillar C above referred to, and its inlet connected to the outlets of a four-way cock, from which pipes are extended to the inlet and to the outlet of the meter, to the inlet of the governor, and to the gas-pillar; so that the pressure at any one of these points may be ascertained, and the working state of the instruments, in respect to friction, or resistance to the passage of gas, determined.

33.—Besides enabling the operator to detect undue friction, the King's gauge enables him to re-adjust, when needful, the consumption of gas to the standard rate without waste of time; for, knowing by experience what pressure should be below the burner under certain conditions, he may at once turn the micrometer on or off to the extent requisite to secure the desired indication of pressure on the gauge. The base of the gauge consists of a rectangular box, through the centre of which passes a cylinder down to within an eighth of an inch of the bottom — the cylinder being much smaller in area than the space about it within the box. Extending upwards from the box are two pillars which support an arc dial and also two cross bars, one in front and the other at the back. Between the bars is a grooved wheel fixed on an arbor, which is free to turn on centres or upon antifriction rollers. The arbor also carries a pointer extending up to the dial. A silk cord passes over the wheel, and is secured to the latter at one point of its circumference. To one end of the cord a float, which descends into the cylinder, is suspended, while the other end of the cord carries a small weight.

34.—The gauge is charged with water, when no gas is entering it and when its vent cock is open, to the height of the socket in front, and, if needful, the pointer shifted on the arbor until the former coincides with the zero of the scale. The vent cock is then closed, and if gas be admitted, its pressure will operate within the box, forcing the water up in the cylinder, thereby causing the float to rise and the wheel above to make part of a revolution and the pointer to traverse over part of the scale, which is greatly enlarged, and indicates to *1-100th of an inch of pressure.* When this gauge is to form part of a new set of instruments, it is advisable that the maker of the photometric apparatus should furnish the bench or table for the photometer fitted complete with the necessary cocks and pipes, as an ordinary gasfitter will scarcely realise what is required.

35.—The Burner. The kind of burner to be employed will, as stated in paragraph 11, depend upon the obligations imposed upon the Gas Company.

36.—The Candles. These should be of the purest sperm, admixed with a small proportion of wax to "break the grain," and should be obtained from the maker of the highest repute, or from those who act as agents for the sale of such maker's candles. Many candles are sold by shopkeepers as "sperm" which possess no claim to the name.

37.—Bunsen Discs. These should be made of paper, as thin as it is possible to manipulate, and the line of separation between the greased and ungreased parts should neither be defined with such absolute hardness as to be distinctly visible in every position between two lights, nor be softened down so much that in any one position the spot becomes quite invisible. In the first case it will be difficult to determine the point of equal illumination, owing to the hardness of the separating line; and in the second case, it will be found to be impossible to decide with certainty upon the point of equal illumination, to the extent possibly of at least one candle's power. The second kind of disc cannot be amended, but the first, or hard line disc, may be easily rendered fit for use, by simply passing it rapidly over a gas flame, then trying it, and if needful, repeating the operation of slightly warming until it is rendered sufficiently sensitive. The disc must be perfectly flat, for if it bulges out when in its holder, and presents a convex surface to one of the flames and a concave surface to the other, the indications obtained will not be correct.

38.—Sometimes Leeson star-discs are used instead of the Bunsen. The Leeson disc consists of three thicknesses of paper, the outer pieces very thin and the middle one somewhat stouter, with a star-shaped hole cut in its centre. These are all pressed as closely together in the disc-holder as possible. The advantage claimed is uniformity in the texture of the surfaces presented to the eye, which certainly is not the case with the Bunsen discs, as the texture of the paper is affected, as well as its colour, by the grease. It has also been claimed for the Leeson disc that it is more sensitive; this, however, the Author has no hesitation in denying. He has worked pretty industriously with both kinds of discs in a sort of competitive way, and *much prefers* the Bunsen. One evil thing, although it may be a small one, about the Leeson disc, is that the surfaces of the papers cannot be brought into absolute contact; hence there is a sensible space between the two outside surfaces, and this defect, for more reasons than one, must tend to falsify the indications afforded by this disc. These discs have been employed in some of the London testing rooms, but the Author has been informed that the Referees intend to prohibit their use in the future.

39.—The Glass Vessel, or Testing Glass for Sulphuretted Hydrogen. The best form of vessel is that shown in fig. 5, which represents a glass cylinder, the ends of which are closed by a base plate and a cover, both of white metal. A pipe which is attached to the base, passes upwards through the cover and terminates with a screwed end, which enters the nut or cap, which is surmounted by a burner. When the nut is screwed down on the cover it causes the cylinder to be compressed between washers of leather, or rubber, within

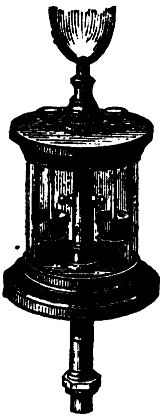


Fig. 5.

the base and cover, and renders the junctions gastight. Within the glass are two cups containing water, while immediately above in the cover are two plugs, each furnished with a clip, which serves to hold a test paper of such length that its end dips into the water cup below. It will be observed that two small jets project from the pipe within the glass. These must be directly opposite the suspended papers. The gas enters by the vertical pipe, escapes through the jets (the vertical pipe being stopped just above the jets), passes through a hole in the upper part, and thence escapes from the burner. The instrument is made with the outlet pipe in the base when it is desired to pass the gas on to the photometer burner, or to any other testing instrument, such as the Referees' Test for Sulphur Compounds "other than sulphuretted hydrogen." The time for exposure of the test papers is, under the Gas Works Clauses Amendment Act, three minutes, or such time as may be fixed [12, (*a*) Part II], but in London the time of exposure is extended to about 20 hours, under conditions which are set forth in the second section of this treatise.

40.—SERVICE GOVERNOR. This may be either of the wet or dry kind. It should always be used when the pressure of supply is likely to vary, and to rise much above that of an inch head of water. It should be weighted to give about 8-10ths of an inch of pressure, and will then prevent undue strain being thrown upon the experimental governor, and thereby greatly assist in the maintenance of a uniform rate of consumption.

41.—THE BAROMETER. Two forms of barometer are shown on page 30, fig. 6, representing the "Standard," which is used when the greatest possible exactness is essential, and fig. 7, representing the "Pediment" barometer, which is generally employed for purposes which do not demand extreme accuracy. Both barometers consist essentially of a long glass tube closed at the top, and with its lower end dipping into a cistern of mercury. The tube being entirely free from air, the mercury forms a column within the tube of such height as to give a pressure equal to that which the atmosphere exercises on an equal area of the cistern.

42.—When the mercury in the barometer tube falls, that in the cistern rises in corresponding proportion, and *vice versâ*, so that there is an ever-varying relation between the level of the mercury in the tube and the mercury in the cistern, which affects the accuracy of the readings. M. Fortin's form of cistern, which is adopted in the Standard barometer, completely obviates this difficulty. The cistern is made of glass, with flexible leather bottom and a brass adjusting screw, as shown in fig. 8. Through the top of the cistern is inserted a small ivory pointer, the lower end of which corresponds with the zero of the scale; and in order that the

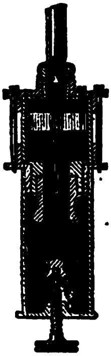


Fig. 8.

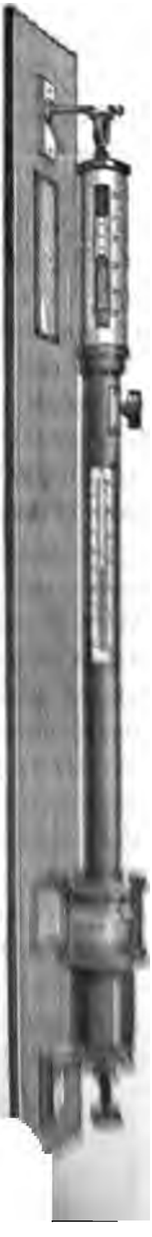


Fig. 6.

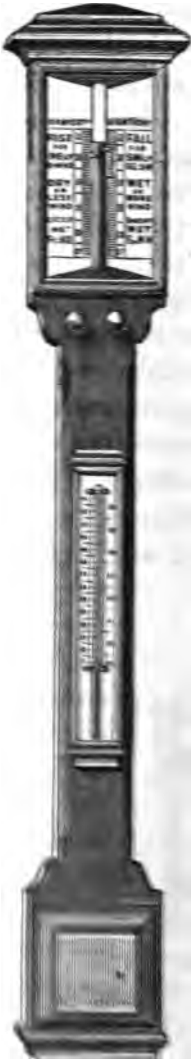


Fig. 7.

readings should possess uniform value, it is necessary that the level of the mercury in the cistern should be adjusted by the screw until the ivory point *appears* to touch its own reflection on the surface. The reading is then taken.

43.—In the best kind of "Pediment" barometers, fig. 7, the variations in the level of the mercury in the cistern are compensated on the scale, each indicated inch of which is less than an inch in length, to an extent proportionate to the relations of *the area* of the tube to the area of the cistern. With this kind of barometer, the accuracy of the indications are dependent on the skill and care exercised by the maker in the compensation. Guaranteed instruments should, therefore, only be employed, as many Pediment barometers are made which are not compensated at all, or but imperfectly so. Properly adjusted instruments of this class may be fairly depended upon for all ordinary purposes,—gas testings included.

44.—The Vernier is a moveable scale for subdividing parts of a fixed scale. By the aid of this instrument, subdivisions of the scale of the Standard barometer may be made to the 1000th of an inch. Fig. 9 shows the scale of a standard barometer, divided into half-tenths or ·05 of an inch. The Vernier, C, D, is made equal to 24 of such divisions, and is divided into 25 equal parts, from whence it follows that one division on the scale is 1-25th of ·05 larger than one on the Vernier, so that it shows a difference of ·002 of an inch. The Vernier reads from ·0, or zero, upwards; D, therefore, indicates the top of the mercurial column. Each division of the Vernier showing a difference of ·002, it follows that *five* divisions show a difference of ·01, or 100th of an inch; hence, every fifth division is numbered.

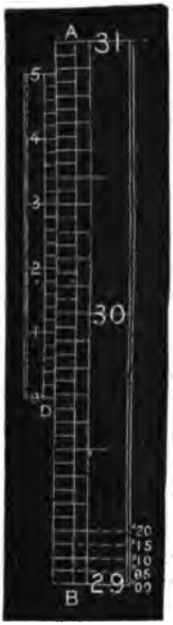


Fig. 9.

45.—In fig. 9, the zero of the Vernier is between 29·65 and 29·7 on the scale. Glancing up the Vernier and scale, the second line above ·03 will be found to coincide with another on the scale; this gives ·03 and ·004 to add to 29·65, so that the actual reading is 29·684. In those instances where no line on the Vernier is found *precisely* to coincide with a line on the scale, and doubt arises as to which from two are equally coincident, the rule is, to take the intermediate 1000th of an inch.

46.—A barometer should be suspended in the shade, and should be perfectly vertical, for the slightest angle will increase the apparent height of the mercury column. The pediment Bar, fig 5, is first prepared for use, after suspension, by applying one of the pinion keys, which is below the scale, to the square-headed screw at the bottom of the instrument, and turning gently to the left until the screw stops. The key is then replaced in its position to operate the Vernier.

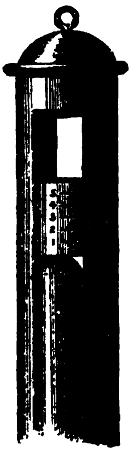


Fig. 10.

47.—In taking a reading with a Standard barometer, it is important that the eye, the zero edge of the Vernier, the top of the mercurial column, and the back of the Vernier, should be on the same horizontal plane (fig. 10), conditions which practice will render attainable. With Pediment barometers the Vernier is in front of the scale, and the zero line of the former must be made to coincide, as nearly as the eye can judge, with the top of the mercurial column.

48.—The scale and Vernier of a Pediment barometer are seldom divided so minutely as those of the Standard kind—the scales being divided into tenths of an inch, and the Verniers made to indicate the 100ths of an inch, which is done by dividing nine-tenths or eleven-tenths of an inch on the Vernier into ten equal parts.

49.—In making barometric observations for comparison with others, it is necessary that all should be reduced to a temperature of 32° F., and also with any tube less than 0·6 of an inch diameter to correct the apparent height of the mercury column for capillarity (unless, indeed, the correction for the latter has been made on the scale), but these refinements are not necessary for photometric purposes, as their effects would be inappreciable.*

50.—The Letheby form of photometer shown in the frontispiece, and the arrangements of the instruments and accessories therewith associated, permit the whole to be nearly on the same level, and to be placed on a table of ordinary height, so that the operator may *sit* instead of being compelled to stand, during his experiments. He is able, moreover, while sitting, to observe the meter index, to regulate the rate of the flow of the gas by the agency of the governor and the micrometer, to pay due regard to the condition of the burning candles, to the candle balance, and to the gas-flame. His eyes are shielded from the direct rays of light from the flames by the screens 2, 2′, hence, being in comparative darkness, he is better able to decide upon the equal illumination of the disc. In addition, the screens 1, 1′; 2, 2′; prevent any rays of light from the flames falling upon objects whence they could be reflected back to the disc. Further, the fixing of the photometer and balance on a base board (suggested to the Author by Dr. Redwood) renders that instrument independent of any troublesome process of "fixing" or "erecting," as these terms are ordinarily understood.

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* Useful manuals, which contain information relative to the Barometer, are "Weather Warnings," published by Houlston & Son, London; "Instructions in the use of Meteorological Instruments," by Robert H. Scott, M.A., F.R.S., to be obtained of Stanford, London. Simmond's Tables, &c.

The Photometer Room.

51.—The Photometer Room should, for the sake of comfort and convenience, be of reasonable dimensions, that is, about 12 feet square and 9 feet in height. It should be well *ventilated,* although *free from draughts,* not subject to vibrations, and should be maintained at a temperature as near to 60° Fahr. as circumstances will permit. A smaller chamber will *do,* say 8 to 10 ft. long and 5 to 6 ft. wide, but the operator will, if cramped for space, experience so much discomfort that he will be tempted to hurry over the operations. Besides which, a very small room will not allow, comfortably, of the presence of a visitor or assistant.

52.—The Photometric Apparatus is best placed next one of the walls of the room,—on a table which must be firm and rigid, with its top surface perfectly level, and 2 ft. 9 inches above the floor line. In lieu of the table a stout shelf may be fixed along the wall. It should be 24 to 30 ins. wide, and at least 8 feet long. The wall behind the table should be coloured dull-black, with flatted paint, or lampblack and size, to the height of about 2 feet above the table-top, or a black cloth may be suspended against the wall. The room should be generally of a somewhat dark colour, but need not be blackened all over.

Fitting up.

53.—Set the apparatus upon the bench or table 52, in the order shown in the frontispiece. Fix the service governor (40) in any convenient position, and from its outlet extend a pipe ½-in. or ⅝-in. bore to the inlet in the centre of the back of the experimental meter (29). Connect the outlet of the meter to the inlet of the governor (31), and the outlet of the latter to the pipe D below the photometer. The two first-mentioned connections must be of metal pipe, but the last *may* be made with a short piece of *red* india rubber tube, but better if with metal pipe. Charge the various instruments, which require it, with water, as explained in pars. 29 and 31; put all the weights on the service governor, and remove all the weights from the counterpoise of the experimental governor.

54.—Turn on the gas and let it pass freely from the pillar C for five to ten minutes, then close the stopcock below A, and try all joints for soundness, then afterwards observe for a few minutes whether the pointers of the meter dial move. If they do, tighten up all the joints so that the meter pointers finally remain stationary for a period of at least five minutes. Be careful that each instrument stands perfectly level on a horizontal plane.

55.—The sulphuretted hydrogen test (39) may be fixed on the photometric table behind one of the screens 1, 1′, or on a bracket against the wall, and a gas pipe connected to it.

56.—The barometer (46) should be hung against the wall of the room in any convenient position for taking readings.

57.—It is advisable that the gas service to the photometric apparatus should extend direct from the main, and be independent of any other lights than those in the testing room.

Preparation of Candles.

58.—The Standard Sperm Candles are 8¾ ins. long from base to shoulder. Cut each candle in two parts at 4⅝ ins. from its base. This is best done by laying the candle on a clean level surface, and rolling it under the edge of a sharp knife. Cut away half an inch of sperm from the top of the *lower* half, and also cut away the sperm cone from the top half; reduce the projecting wick of the latter to half an inch in length. Take great care, in cutting away the sperm, not to injure the wicks in the slightest degree. Burn the pieces of candles not too closely together, in a place free from draughts, until the flames attain their maximum size, and each wick bends over and presents a red point through the flame, then touch it with a piece of sperm and blow out the flame. *Always extinguish candles in the way described, and thus preserve their wicks in good condition.**

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* Some operators prefer to invert the upper half of the candle, and burn from its centre, but the Author sees no advantage in this plan.

59.—If any of the candles burn badly, smoke, form very irregular sperm cups about the wicks, or gutter, *reject them*, unless they can be made, by judicious treatment, to burn properly. They may sometimes be made to burn with regular cups, by paring away the irregular parts. Any candles with their wicks much out of centre should be at once rejected. Store the selected pieces in a place of moderate temperature, and where the wicks will be safe from injury. The following from "Remarks on Photometry," a paper by the Author, read before the British Association of Gas Managers, June 8th, 1870, expresses some of the characteristics of a good sperm candle:—

> In respect to the selection of candles for experiment, there are certain appearances about a good sperm candle when burning (and all must be burned preliminarily, to get them into a proper condition for use) which go far to show whether the candle is or is not a fair specimen. These appearances can be much better practically illustrated than described, but the writer may mention some of them. The candle should burn with a shallow cup, and the sperm within an eighth of an inch of the top of the candle should, after it has been burning some time, be firm, and bear a good squeeze between the finger and thumb without yielding to the pressure. The wick should appear somewhat small and compactly woven, and not bend to an exceeding degree out of the upright. Lastly, on looking down into the sperm cup, there should appear to be a number of radial dashes (something like the dotted lines in a drawing, but much more irregular) extending from the wick to the circumference. If a candle contains paraffin or stearine, some or all of these peculiarities are wanting. The cup will be deeper, its edge will soften and give way to a very slight pressure, the

wick will be generally larger, and there will be no appearance of radial lines in the sperm cup. The peculiarities mentioned apply in part, however, only to candles which have been made some little time. Candles which are quite new generally burn somewhat irregularly, and the radial dashes in the cup are mostly absent, doubtless owing to a temporary disturbance of molecular arrangement, consequent on the heating of the sperm when the candles are made.

The conditions under which a candle is burned exercise a material influence on the amount of light which it yields, as well as upon the rate of consumption and uniformity of the light. The atmosphere surrounding it should be tranquil, otherwise the candle is almost certain to form an irregular cup, to gutter, and to smoke. If in a tranquil atmosphere the candle burns thus irregularly, it is an evidence of its unfitness for photometrical use. The candle may be fairly protected by screens from draughts, but not, the writer thinks, absolutely enclosed in a box, inasmuch as, when so enclosed, the surrounding air may (unless, indeed, the box be enormously capacious) be somewhat heated, the supply be not so free, and the candle be burned, in consequence, under abnormal conditions. Moreover, when so enclosed, its condition is not so readily observed by the operator. * * *

At first the idea of selecting the candles may seem to involve the conclusion that the operator might make the gas to appear good or bad at will; but in fact the selection would have just the contrary effect, and would narrow the boundaries within which errors might be made . . . . . when exactness is required, and especially when tests are made against a gas company, the results of which may subject the company both to pecuniary penalties and to discredit, no photometric estimation of the value of the gas should be accepted which was based upon less than three or even four consecutive experiments with different candles, each experiment lasting for at least ten minutes, so that an operator might easily make the whole test in one hour; or if, as in many country towns, this would involve too much labour, if done in one evening, the examiner might make one trial on each of four evenings in a week, and then the average of the whole would represent the illuminating value for the week.

If, in such a series, one of the experiments should work out very discordantly with the rest, that experiment should be rejected, and a fresh experiment be made, or, if that be not possible, a mean taken from those experiments which were nearer in agreement. Such a practice would go far towards securing agreement between the results of different operators.

60.—It is to be remarked that many operators prefer to burn the upper half of the candle from the point at which it is cut towards its apex, the object being to approximate more nearly to uniform light and consumption, for as a candle tapers throughout its length, the lower half is continually increasing its diameter about the wick as it burns down, while the *inverted* upper half is as continually diminishing. The Author, however, has used candles in both ways, and prefers that which he has recommended, as the compensation afforded by the other method is more theoretical than real.

Testing Operations.

61.—Take the upper and the lower halves of one candle, or the lower half of one and the upper half of another, and place them in the candle-holders of the balance, so that at least an inch of each candle projects above the top of its holder. Warm the sperm about the wicks with a lighted taper, and ignite the wicks fully and completely. Let them burn for at least ten minutes (para. 12, Part II.), so that the flames shall attain their maximum size.

62.—The candles should be so placed in the holders that their wicks should bend away from each other, and in directions at right-angles with the line of the photometer bar. By this arrangement the *centres* of the flames will be made to coincide with the terminal point of the photometer. Some operators place the candles so that the line of bending of the wicks shall be *parallel* with the line of the bar, but with one wick bending over *towards*, and the other bending *away from*, the disc; but this plan is not so good as the one recommended.

63.—The position of the wicks relative to the disc or bar is very important, for if the points of both wicks are turned *towards* the disc, the gas will be prejudiced, and if both are turned *away from* the disc, the apparent value of the gas will be unduly exalted in the comparisons, because in the first case the true centres of the flames will be *nearer* to, and in the second case *further* from the gas-flame than they ought to be.

64.—The adjustment of the gas to the 5 c. ft. rate per hour may be effected while the candles are preliminarily burning, especially if only one minute-clock be had for timing the rates of consumption, both of the gas and of the candles.

65.—At the outset ascertain whether the meter, the governor, or governors, and also the gauge, are properly charged with water (29, 31, 40, 34),* then turn on the gas, and weight the service governor to give about ·8 of an inch pressure. Screw the burner, which in the absence of any obligation to the contrary (35) should be, for common gas, a No. 1 London Argand; use with the size of chimney which will give the best result (10), which will be ascertained on trial. *Clean the chimney thoroughly before placing it on the burner, and do so on every after occasion before commencing the testings.* Fully open the micrometer cock (D. 20), and the stop-cock on the same tube. Place as many of the loose brass-weights upon the constant weight suspended from the beam of the experimental-governor, as will cause the gas to be delivered from the burner at the rate of about 5½ c. ft. per hour. In this and in the after operations the sliding weight on the governor beam may be used with advantage.

66.—When the rate of delivery is sufficiently reduced, operate with the micrometer until the short pointer of the meter makes exactly one revolution per minute. This may take some time, but, all conditions as to pressure remaining constant, the micrometer will need but little motion after it is once set.

67.—Until quite familiar with the operations, it is best to start with both clock and meter at zero. Raise the stopping lever of the clock, press smartly on the top button, and the clock hands will fly to zero. Turn the small pointer of the meter back until the long pointer is upright, and the small one overturned to the figure 4. Release, and as soon as the small pointer reaches the figure 5, swiftly press down the side lever of the clock.

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* The water-level of each of these instruments must be examined, and, if needful, readjusted at least as often as at intervals of 7 days, and *most* importantly the water-levels of the meter and gauge.—See Appendix E.

68.—Let both run for ten minutes, at the end of which time note the position of the meter hands, as explained on pars. 26 and 27. Take every care to secure 5 ft. rate. Small divergences, such as 4·9 or 5·1, may be permitted and corrected for, but much greater ones should not be permitted.

69.—*In every case burn the gas for 15 minutes before making any testings for illuminating power.*

70.—Turn next to the candles. If they have burned down much, push them up until fully an inch projects above the holders. Stop the clock, and set it again at zero. Nearly counterpoise the candles with weights, shot, or glass beads, leaving the candles a trifle heavier than the counterpoise. Watch the balance until the candles and the opposing weights become equipoised, and the pointer of the balance reaches the centre of its index. Instantly start the clock. Place 40 grains in the pan of the candle-holders, and proceed to make observations of the relative illuminating power of the gas and candles.

Readings.

71.—Move the slide carrying the photometer disc between the gas and candle flames, until a position is reached at which the spot on the disc is nearly invisible, or both sides are equally illuminated. Observe the graduation (18 and 19) on which the pointer of the slide rests, and record on paper. Make ten such observations *within ten minutes*, then give entire attention to the candle balance, and when it again turns and its pointer reaches the centre of the scale, stop the clock, and note on paper the number of minutes and seconds during which 40 grains of sperm were burned.

72.—It is to be observed that some little practice is necessary to determine the position of equal illumination of the disc, for, owing to the difference in the colour of the lights usually contrasted; the difference in the texture of the greased and ungreased parts of the disc, etc., the spot seldom becomes invisible; but experience soon enables the operator to decide with certainty respecting equality of illumination (37).

73.—Supposing the ten consecutive readings of illuminating power to be as in the margin, the mean is 8·56, which, multiplied by *two*, as *two candles* are employed, indicates an illuminating power for the gas of 17·12 candles.

$$\begin{array}{r} 8{\cdot}6 \\ 8{\cdot}4 \\ 8{\cdot}5 \\ 8{\cdot}5 \\ 8{\cdot}6 \\ 8{\cdot}6 \\ 8{\cdot}5 \\ 8{\cdot}6 \\ 8{\cdot}7 \\ 8{\cdot}6 \\ \hline 10)85{\cdot}6 \\ \hline 8{\cdot}56 \\ 2 \\ \hline 17{\cdot}12 \end{array}$$

74.—Such a result as that just indicated would only be accepted as correct under the following conditions, viz.:—

> *That the gas had been burned at the rate of exactly 5 c. ft. per hour.*
>
> *That the candles had burned at the rate of 120 grains each per hour, or that the two had burned 40 grains in ten minutes.*
>
> *That the height of barometer had been 30 inches, and the temperature 60° F.**

75.—Too much care cannot be exercised in adjusting the gas consumption to the exact 5 c. ft. rate, but supposing that the rate was found to be 4·9 instead of 5 c. ft. (26, 27), then correction must be made. The Referees make no mention of a correction of this kind, but direct that "the rate of burning of the gas shall "be five cubic feet per hour—a rate of consumption "which is shown by the hand of the meter making "exactly one revolution per minute for several minutes "consecutively."

Correction for Gas Consumpt.

76.—Multiply the average illuminating power by 5, and divide by the actual rate of burning. *Ex.:*

Average of readings . .	17·12
Standard rate	5
Actual do.	4·9)85·60
Corrected average .	17·46

---

* The temperature to be taken is that of the gas passing from the meter, and not that of the air.

77.—The range allowed in the consumption of the candles (8) corresponds very nearly for two candles with the burning of 40 grains in 10½ minutes for the *lowest* rate, and with 9½ minutes for the *highest* rate.

Correction for Candles' Consumpt.

78.—*Multiply the average illuminating power (after any needful correction for gas) by the time in seconds due to the Standard rate, and divide the product by the actual time of burning. Ex.* :—

Corrected average, for gas consumpt
as per par. 76 . . . . 17·46
Time due to 40 grains, in seconds . 600

Time actually occupied, say
9 mins. 34 secs., = secs. . . . 574)10476·00(18·25

Corrected average . . . . . . 18·25 candles.

Corrections for Barometric Pressure and Temperature
(13 to 16, 41 to 49.)

79.—Multiply the corrected average *last obtained* by 1,000, and divide the sum by the number which is in the table C of Appendix, in line with the observed barometric pressure and under the observed temperature, which last must be that of the gas, as stated in the note to par. 74.

Ex. :—Corrected average as above, multiplied by
1000 18250
Bar. 30·3. Temp. 52°. Tab. No., 1030.
1030) 18250 (17·71 candles.

80.—In the first edition of "Photometry," which the Author published early in 1871, he states that it is not sufficient, when exactness is demanded, which is the case when the illuminating power of the gas is sought for scientific purposes, or when it is sought for the purpose of ascertaining whether a gas company is fulfilling its obligations to the public, to deduce its illuminating power from any *one set* of ten observations, or from repeated sets of observations, against the light produced by the *same* candle or the *same* pair of candles; the gas-light should be compared against the light of *different* candles or pairs of candles, and the apparent illuminating value be taken as equal to the mean of the whole series of observations. The Referees require each gas-examiner to make *three tests* daily, but say nothing about using different candles in each testing, but without doubt this is done. Their instructions are as follow:

> "The average of each set of ten observations "is to be taken as representing the illuminating "power for that testing, and the average of the "three testings is to be taken as representing the "illuminating power of the gas for the day."

81.—The Referees' directions as to corrections are as under, and, as before said, do not provide for any deviation in the rate of consumption of gas.

The calculations for working out the corrections, &c., for the illuminating power of the gas proceed in the following manner. Add the observations together and divide the sum by 10 to get the average; then, as two candles are used, multiply by 2, to get the illuminating power of the gas if tried against one candle. Then, as the standard rate of consumption of the candles (viz. 120 grains) is to the average number of grains consumed by each per hour, so is the above-obtained number to the actual Illuminating Power. Finally, make the correction for Temperature and Pressure, by dividing the illuminating power by the Tabular number. For example (taking the Tabular number as 1·025):—

Observations—

1st minute—7·6
2nd „ 7·4
3rd „ 7·3
4th „ 7·5
5th „ 7·8
6th „ 7·4
7th „ 7·4
8th „ 7·5
9th „ 7·5
10th „ 7·4

10)74·8

Consumption of the 2 candles in 10 minutes, = 41 grains.
3

123 = Consumption of 1 candle per hour.

Average, by 2 candles, = 7·48
2

Average, by 1 candle, = 14·96
Consumption by one candle per hour . } 123 grains.

4488
2992
1496

Carried forward 1840·08

Standard consumption 120)1840·08
Correction for temp.
and pres. [Table C.] 1·025)15·334(14·9 = corrected Illum. Power in candles.
1025
5084
4100
9840

The foregoing calculation can be shortened as follows, which is the form prescribed in Appendix D.

Observations—1st minute — 7·6
2nd „ 7·4
3rd „ 7·3
4th „ 7·5
5th „ 7·8
6th „ 7·4
7th „ 7·4
8th „ 7·5
9th „ 7·5
10th „ 7·4

Average, by 2 candles, = 7·48
Consumption by two candles in 10 minutes . } 41 grains.

748
2992
20)306·68
Tabular number
Table C. . . . 1·025)15·334(14·9 = corrected Illum. Power in candles.
1025
5084
4100
9840

82.—The gas consumpt may be corrected, and the Referees' shortest and prescribed method, as given in the last paragraph, adopted, instead of those in pp. 76 and 78, by using the numbers in the Tables A and B, and working in accordance with the rules which accompany them.

Ex.:—Observations: 1st minute	8·2
2nd "	8·1
3rd "	8·1
4th "	8·0
5th "	7·9
6th "	7·9
7th "	7·8
8th "	8·0
9th "	7·9
10th "	7·9
Average by 2 candles	7·98
Gas rate, 4·9; multiplier, by Table A, Appendix, 1·02	1·02
	1596
	7980
Corrected for gas rate (75). .	8·14
Candles: time occupied in burning 40 grains sperm, 9 mins. 34 secs. instead of 10 mins=consumpt for 10 mins. by Table B, Appendix, 41·81 grains	41·81
	814
	6512
	814
	3256
Total carried forward. .	340·3334

Divide the sum by 20, or point off an additional decimal place to the left and divide by 2. . . *Ex.* 2)34·03(=17·01

Multiply by 1000, and divide by the number (Table C, Appendix) for the observed pressure and temperature—say bar. 30·3 and ther. 50° = 1030 . . . 1030)17010(16·51 Corrected Illum. Pow.

1030

6710

6180

5300

5150*

83.—The Referees direct that "the gas-examiner "shall record his observations and calculations for "determining illuminating power in the form pre-"scribed"—which form will be found at D in the Appendix, with figures filled in by the Author. It will be observed that all the calculations are shown in detail, except that which may sometimes need to be made for excess or deficit in the consumption rate of the gas.

84.—When done with for the time being, extinguish the candles (58), taking care to preserve the wicks in good condition. Leave the micrometer and governor in adjustment, and turn down, or turn off, the gas to the burner, by means of the stopcock to the left of the micrometer.*

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* To shorten the calculation, instead of dividing by 20 and multiplying by 1000, the sum (340·3) may be multiplied by 50, and the Tabular number then used to divide.

ORDINARY PHOTOMETERS.

85.—In years gone by, photometers of more primitive construction than that hereinbefore described, were permitted to be and were used for official testings. Such an instrument, as constructed by the late Mr. King, of Liverpool, is shown in the annexed print. The bar may be 50, 60, 75 or 100 inches in length between the lights—generally of the greater length—and is supported at one end by the candle pillar and at the other end by the gas pillar, the latter being provided with a micrometer and pressure gauge. The graduations on the bar are, of course, proportioned to the length. The slide has no rollers (20), nor has the disc-holder any reflectors. The meter and governor are identical with those already described, but the balance, E, is different from, and inferior to, that of the Standard photometer, while the clock is of the pendulum kind, and beats seconds. It also strikes every minute, giving warning by a click five seconds before striking. Such clocks are still frequently used with the Standard apparatus.

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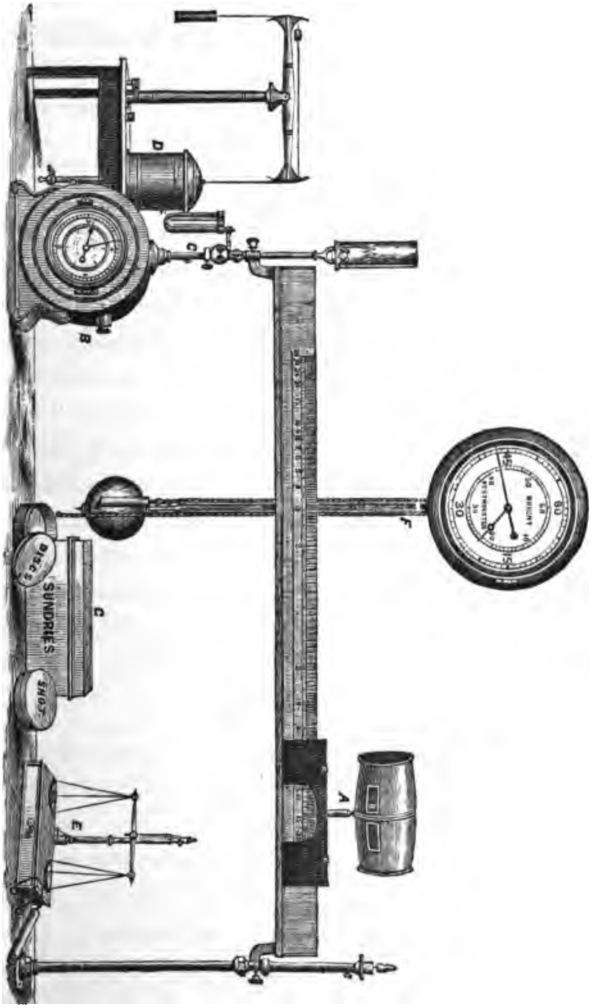
* The test for sulphuretted hydrogen may be made at any convenient time, while matters are getting ready for photometric testings. See par. 39. If a foul paper results, it is usual to date it, and keep it for reference in a dark place, and within a stoppered bottle.


A
B
C
C
D
E
F
SUNDRIES
DISCS
SHOT
WEIGHT
POSTMASTER
15
30
45
60

86.—This kind of photometer is sometimes employed by burner makers, in commercial determination of the value of gas produced from various coals, etc., and, in a modified form, by candle and lamp manufacturers.

87.—The meter, governor, and gauge, must be charged with water, and the gas adjusted to Standard rate, as described under "testing operations" with the Standard photometer (65 *et seq.*), but the method of taking the time is, of course, different. The clock weight is pulled up by its cord and the pendulum set in motion, and when it has attained its proper swing, the short pointer of the meter index may be turned back to zero, and kept close thereto by gently touching until the clock strikes; the time is then noted, and the agreement of the speed of the meter with that of the clock confirmed by observing the meter during several minutes. It is quite easy, however, to determine the extent of any excess or deficit in consumption during ten minutes (26) with the pendulum clock.

88.—In the old way of operating, the candle, in a proper condition for use (58 *et seq.*), was first weighed along with a small piece of sperm, then, when the clock struck at some observed minute, the wick was lighted as fully as possible, and the candle at once placed in the socket at the end of the bar. At the end of the 10th minute, when the 10 photometric readings were completed, the flame was blown out, after the wick had been touched with the piece of sperm which was weighed along with the candle, and both were returned to the balance and reweighed. This method is highly objectionable,* and a better, although

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* Another important matter is the accurate determination of the rate of consumption of the candles. The writer is fully aware that most photometrists take the utmost care in this matter, and find the rate even to the 100th of a grain; but there are some who are content to use scales not capable of weighing closer than half-a-grain. Now if, for the sake of argument, it is admitted as a fact that, within certain narrow limits, the light yielded by a candle is in direct proportion to the quantity of material consumed, then such a defect in weighing, with one candle and ten minutes as the time of burning, would induce an error of 2½ per cent., which, in 14-candle gas, would amount to more than a third of a candle's value.

The method of weighing the candle before lighting, using at the photometer, extinguishing and reweighing, should be utterly discarded; not on the ground that the weighing may be inaccurate, but because the candle cannot, in an instant, be completely put in a proper state of burning, and consequently the readings of the photometer during the first two or even three minutes will be much above the real comparative value of the gas.

The real lighting value of a candle may be considered as the average of its light during the whole time it burns, and as the average of its light during the first ten minutes after ignition would be undoubtedly considerably lower than the average for the whole time during which it is capable of burning, it is manifestly unfair to employ the candle under the conditions mentioned.

Even the ordinary system of weighing the candle while burning at its best, then removing it from the balance to the photometer, and thence again in due time to the balance, is objectionable—first, on account of the needless trouble thrown upon the operator, and, more importantly, on account of the liability to disturb the regularity of combustion by the necessary motion, and also to destroy an experiment by the dropping or spilling of sperm.

The only method of weighing which is at once rational, facile, still imperfect method, is, to put the candle in a holder which can be removed from the candle pillar. Let the candle burn steadily for ten minutes; then place the holder, with the burning candle and a small piece of sperm, in a suitable balance. Nearly counterpoise the candle with weights (70). Observe what number of minutes and seconds are indicated by the clock, and count on in seconds (beats) until the balance turns. Note the time on paper. Gently remove the candle to its position on the pillar, taking care that the wick bends over in a direction at right angles with the line of the bar (62).

89.—After completing the observations with the photometer (61—73), and just before the expiration of the ten minutes, gently remove the candle socket from the pillar, and, when time is up, touch the wick with the piece of sperm, blow out the flame, and return all to the balance. Counterpoise by adding weights on the candle side; the number of grains and parts of a grain required, will be equal to the weight of sperm burned if the operations be properly conducted; with the exception of a small error, due to the different conditions of weighing—the upward draught with a lighted candle causing its *apparent*, to be less than its *actual* weight. The error, however, is very trifling, and is mentioned merely as a matter of interest, for

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and accurate, is that in which the candles are weighed *in situ*; that is, while in position for photometric comparison.—"*Remarks on Photometry.*"

it is not likely that any differencee would be discovered with an ordinary balance.

90.—Supposing the readings were as in the margin, the average indicates an illuminating power of 14·39 candles. Correct for excess or deficit in gas consumption (Appendix, Table A.), and multiply the average by 20 (the number of grains which ought to be burned by *one* candle in 10 minutes), and divide by the actual number of grains of sperm burned. Finally, if exactness be desired, correct for pressure and temperature (79).

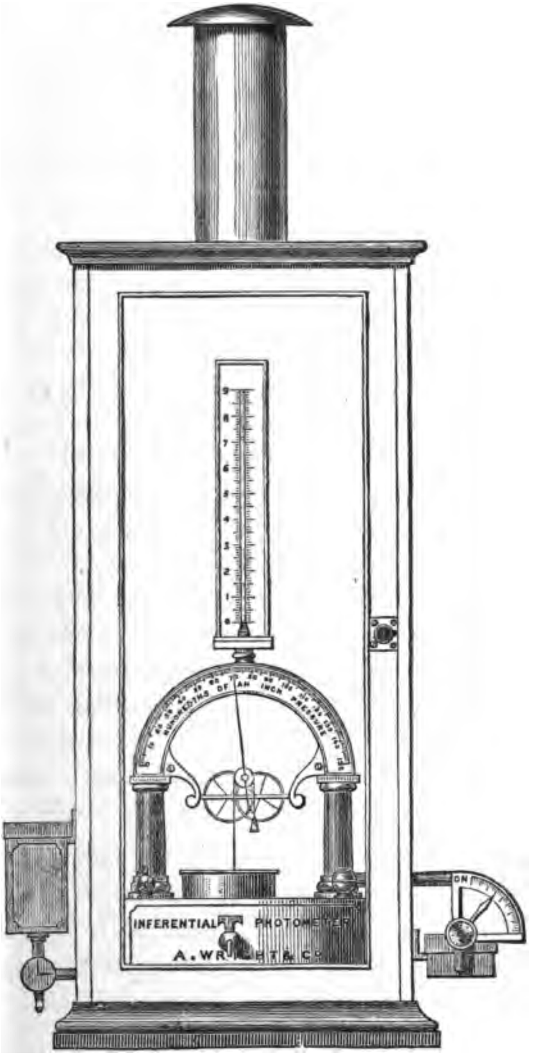
14·4
14·5
14·4
14·3
14·3
14·3
14·4
14·5
14·4
14·4
10)143.9
14·39

THE INFERENTIAL OR JET PHOTOMETER.

91.—The late Mr. Geo. Lowe is entitled to the credit of having applied the Jet Photometer as a constant indicator of the quality of the gas being manufactured. For this purpose it is invaluable to the gas maker; a moment's inspection of the height of the jet flame, produced under a constant pressure, indicating to him whether the gas is sufficiently good in quality, and if not, the necessity of an immediate investigation and the adoption of remedial measures. Doubtless other engineers also applied the jet in a similar manner, and for the same purpose, but there is reason for believing that their contrivances were less perfect than Mr. Lowe's, and that they attached less importance to the indications of the instrument than that gentleman did.

92.—Dr. Fyfe of Aberdeen, however, regarded the jet with great favour when used as a *durability test*, *i.e.*, when used to discover how many minutes a cubic foot of gas would maintain a flame of specific length. Dr. Fyfe was not, however, satisfied that this method, by itself, indicated the actual relative value of gases, but supplemented the durability test by condensation with chlorine, and combined the results of the two tests. Hence, his experiments and statements (published in the "Journal of Gas-Lighting," in 1849) were regarded, probably, as of doubtful value, and the durability-test, in consequence, was somewhat discredited.

93.—The Jet Photometer is represented in the engraving. It is a delicately constructed King's gauge, similar to that described in par. 32, but it is surmounted by a steatite jet burner, in front of and behind which are glass plates, graduated upwards from the level of the burner top, into inches and tenths of an inch. The gauge is enclosed in a glazed wood case, having a copper chimney on its top. On one side of the case two dry governors are fixed, through both of which the gas passes, the second one being weighted to give a lesser pressure than the first. From the outlet of the second governor the gas is conducted through a pipe furnished with a regulating cock to the gauge. By these appliances the gas pressure is readily adjusted, and its regularity maintained. On the opposite side of the box a water cistern is fixed, and by means of a


0
1
2
3
4
5
6
7
8
9
HUNDREDTHS OF AN INCH PRESSURE
INFERENTIAL PHOTOMETER
A. WRIGHT & Co
ON

three-way cock beneath, water may be admitted into, or be allowed to escape from, the gauge.

To set the Jet Photometer at work.

94.—Set the instrument on a firm and level base or support. Carefully remove the float and the packing paper from the cylinder. Replace the float in the cylinder, so that its cord lies in the front groove of the wheel above it. Pass the cord of the weight round the back groove of the wheel, and let the weight hang in opposition to the float. Take care not to strain the cords. Attach a gas supply pipe to the inlet of the governor. Pour water gently into the cylinder until the pointer exactly reaches the zero of the pressure scale. If too much water be put in, draw off the necessary quantity from the side cock. Turn on the gas, ignite it at the jet, and apply a sufficient number of shot or of pieces of metal to the second diaphragm of the double governor to cause the gauge to indicate say 8 or 9-10ths pressure. Put the glass scales in their position behind and before the burner, and make any further reduction which may be needed in pressure, by the aid of the cock or valve at the side of the instrument. Readjust the water level once a day.

95.—The instrument is sometimes "rated," *i.e.*, the length of flame corresponding to a certain quality of gas delivered under a certain pressure is determined by the maker, but the writer thinks that every gas manager should determine for himself the value of the indications of the instrument which he employs. This he can easily do if he has a Bunsen photometer and is in the habit of using it, the additional trouble which is needful being very small. The advantages of this course are, that the manager would satisfy himself respecting the degree of confidence to be put in the particular instrument supplied to him, and if he extended his observations over a period of a few weeks, he would be able to construct a table of reference of great value.

To Rate the Jet Photometer.

96.—Connect the instrument, as above directed, to the service pipe from which the gas is supplied to a Bunsen Photometer. Make *ten* observations with the Bunsen Photometer (61 *et seq.*), and as nearly simultaneously as possible with each of the observations note the length of the jet flame and the acting pressure. Take the mean of the lengths of the jet flame, and record it in a book, together with the mean of the pressures, if necessary. The pressure should not, however, vary. Record also the illuminating power of the gas as determined by the Bunsen Photometer. Repeat the experiment, using a second candle or pair of candles. Continue the comparative experiments until a table, embracing a sufficient number of observations, has been constructed.

SECTION II.

THE
ESTIMATION OF IMPURITIES IN COAL-GAS.

97.—Most of the Gas Companies in the United Kingdom are under no more stringent obligations in respect to the purity of the gas they supply, than that which is specified in the Schedule A, Part II. of the Gas Works Clauses Act of 1871 (see par. 12). But when any Gas Company is under obligations similar to those imposed upon the Gas Companies of London, then it becomes the duty of the Analyst to ascertain, not only (1) the freedom of the gas from sulphuretted hydrogen, but also (2) the quantity of ammonia, and (3) the quantity of sulphur, " other than sulphuretted hydrogen," which 100 cubic feet of the gas contains.

Duration and Mode of Testing in London.

98.—The testings extend over twenty hours of each day, and are made on 10 cubic feet of gas, tested successively for each of the following impurities.

99.—Sulphuretted Hydrogen. The gas as it leaves the service-pipe passes through an apparatus, in which are suspended slips of bibulous paper, impregnated with basic acetate of lead (39).

100.—AMMONIA. The gas on its exit from the apparatus above-mentioned, passes through another apparatus, consisting of a glass cylinder filled with glass beads, which have been moistened with a measured quantity of standard sulphuric acid. For want of a better name this vessel may be called the "Saturator."

101.—SULPHUR COMPOUNDS. On leaving the "saturator" the gas passes next through a meter, by means of which the rate of flow can be adjusted to half a cubic foot per hour, which meter is provided with a self-acting movement for shutting off the gas when ten cubic feet have passed. From the meter the gas passes to the "sulphur test," where it is burned in air impregnated with ammonia; the water vapour which is formed being condensed and collected, and with it the sulphur and other condensible products which arise from combustion.

102.—The arresting of the ammonia by acid, and the burning of the gas under the conditions indicated, are preliminary processes. The after processes consist in the finding (1) the quantity of acid which has entered into combination with the ammonia from the gas, and (2) the weight of barium sulphate precipitated from the condensed products of combustion on the addition of barium chloride.

Preparation of Solutions.

103.—For estimating the quantity of ammonia in gas two solutions are required, one containing 1 grain of ammonia (NH_3) in 100 measures of the solution, the other containing a little more than 2·88 grains of sulphuric acid (SO_4H_2) in 25 measures of the solution, *i.e.*, such a quantity of acid as will combine with and completely neutralise *one* grain of ammonia, and for the preparation and use of these the following glass vessels are required:—a mixing jar (fig. 11) graduated into 100 parts, which, when charged with any fluid to the 100th line, *while standing on a level base,* measures exactly one-tenth of a gallon of such fluid; pipettes (fig. 12), which, when charged with liquid up to the mark on the stem, deliver an exact number of septems; two burettes (fig. 13), on a wooden stand, S, one for use with acid solution, and the other for use with alkaline solution. Each burette is graduated into 100 parts (septems), and each part is subdivided into fifths. A septem is equal to the one ten-thousandth part of a gallon, or to seven grains weight of pure water at 62° Fahr. These burettes are furnished with Mohr's pinch-

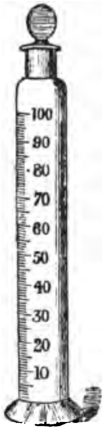


Fig. 11.

Fig. 12.

cocks, P, P′, Erdmann's floats, E, E′, and with funnels, F, F′.

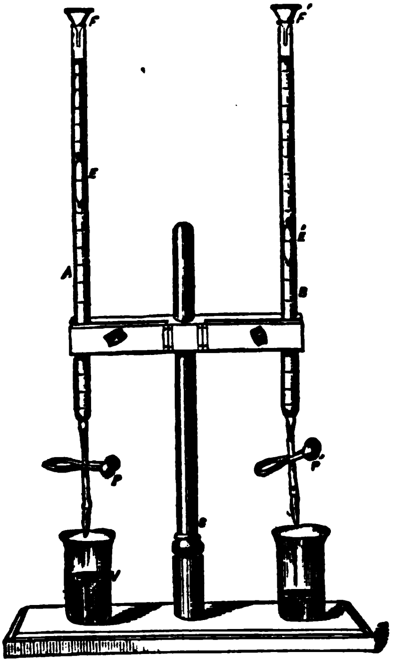


Fig. 13.

104.—SULPHURIC ACID. The gravity of pure strong acid is 1·848, its composition $SO_4\ H_2$, and its combining weight 98. The weight of the two molecules of ammonia, required to satisfy 98 of strong acid, is 34; so that 2·8824 grains of the acid are required to combine with one grain of ammonia. One septem of such acid weighs 12·922 grains; consequently, about 9·2 septems of it are required in the deci-gallon of the solution, which should neutralise four times its own volume of the standard ammonia solution; but, as strong acid is likely to be somewhat below 1·848 gravity, it is better to have a slightly excessive quantity; therefore charge the deci-gallon mixer while it

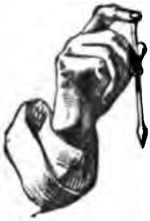


Fig. 14.

stands on a level base with pure distilled water* until the centre of the meniscus or hollow of the water surface coincides with the *top* line of the mixer, then add as nearly as possible 9·4 septems of pure concentrated sulphuric acid, which may be accomplished either by the use of a properly divided burette or by the assistance of a graduated pipette. If the latter, hold the pipette between the fingers and thumb, dip the pipette into the strong acid until it is charged up to the requisite line on the stem. Press the forefinger, previously moistened, firmly on the opening at the upper end, fig. 14., and pass the pipette and contents over to the open mouth of the mixer. Lift the forefinger, and the contents of the pipette will fall into the mixer. Insert the stopper of the mixer tightly and well shake the vessel.

105.—If it be desired to prepare a larger quantity of the test acid at one time, "Measure a gallon of dis-" tilled water into a clean glass jar or other suitable " vessel. Add to this 94 septems of pure concentrated " sulphuric acid and mix thoroughly." A *deci-gallon* of water and 9·4 septems of strong acid will together equal the volume of 1006·9 instead of 1009·4 septems, while a gallon of water with 94 septems of concentrated acid will of course be equal to 10,069 septems.

---

* Water containing impurities is sometimes sold as "distilled." Acidulate a portion with a few drops of diluted hydrochloric acid, and then add chloride of barium solution. Add to another portion diluted nitric acid, and then a little nitrate of silver solution. Both portions should remain clear.

106.—To determine the strength of the test acid remove 50 septems of it from the mixer or vessel in the following manner:—take a clean and dry 50 septem pipette, dip *its point* into the solution, apply the lips to the upper end and suck* until the liquid rises to a little above the mark on the stem. Cease sucking, and immediately press the finger on the top, in the way directed in par. 104. The pipette can be properly charged only in this way when used as an exact measure, as its exterior must then be kept dry.

107.—Hold the pipette before the eyes, and, by partly raising the forefinger, allow any excess of acid to drop from the point into the mixer, until the centre of the curved surface of the liquid coincides with the mark on the stem; immediately transfer the 50 septems of liquid to a clean beaker or flask, and to ensure the delivery of the last drop, gently blow through the pipette while its point is touching the side of the glass vessel.

108.—Treat the liquid with barium chloride, and determine the quantity of sulphate produced as described in par. 136 *et seq.* "The weight of barium "sulphate which 50 septems of test acid should yield "is 13·8 grains. The weight obtained with dilute acid "prepared as above will be somewhat greater, unless "the sulphuric acid used had a specific gravity below "1·848." To determine the quantity of water which must be added to the solution, divide the number of septems of test acid contained in the mixer or vessel by 13·8, and multiply the quotient by the difference between 13·8 grains and the number of grains of sulphate obtained.

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* Caution must be used in filling the pipette with solutions, in order to avoid their entry into the mouth. The point of the pipette must be kept well immersed while sucking. Strong ammonia, strong acids, and all fluids which give off fumes of poisonous or irritating character, must not be so sucked.

109.—Thus, with a *deci-gallon* of water and 9·4 septems of strong acid, the original volume will be 1006·9 septems, and after 50 septems have been removed there will remain 956·9 septems, which, divided by 13·8, gives a quotient of 69·34. If the excess of sulphate be 0·15 grain, then 69·34 × 0·15 gives 10·4, the number of septems of water needful to be added.

110.—If a gallon of water be used with 94 septems of strong acid, the original volume will be 10,069 septems, and after the abstraction of 50 septems there will remain 10,019 septems, which, divided by 13·8, will give a quotient of 726, which, multiplied by 0·15, will give 108·9 septems as the quantity of water to be added.

111.—"If these operations have been accurately "performed, a second precipitation and weighing of "the barium sulphate obtainable from 50 septems of "the test acid will give nearly the correct number of "13·8 grains. If the weight exceed 13·9 or fall "below 13·7, more water or sulphuric acid must be "added until the weight falls within those limits."

112.—If, on a second precipitation and weighing, the test acid is found still to be too strong, the additional quantity of water to be added may be found by the above rule, but regard must be given to the quantity of solution, thus:—the 956·9 septems mentioned (109) will have been increased to 967·3, about, by the addition of 10·4 septems of water, and, after the abstraction of 50 septems for a second test, there will remain 917·3 septems only to be divided by 13·8, in order to obtain a quotient to be multiplied by the excess weight of sulphate obtained. "The test acid thus prepared should "be transferred at once to stoppered bottles which have "been well drained and duly labelled."

113.—AMMONIA. Strong solution of ammonia has usually a gravity of about ·88, and contains about two grains of absolute ammonia (NH_3) per septem. Hence 5 septems to the deci-gallon should give a solution of nearly the right strength. If it be desired to make a larger quantity, measure a gallon of distilled water into a clean glass vessel, "and mix it with 50 septems "of strong solution of ammonia (sp. gr. 0·88). Try "whether 100 septems of the test alkali thus prepared "will neutralise 25 of the test acid; if the acid is just "neutralised by the last few drops, the test alkali is

" of the required strength." To perform this experiment, the burettes (fig. 13) must be used.

114.—Fix the burettes perfectly upright, at a convenient elevation on the stand. Pour a few septems of the ammonia solution into the burette A. Place a glass beaker, V, below the burette, open the pinchcock, and let the solution flow out. Charge the burette fully with a fresh portion of the solution, and remove the funnel. Charge the burette B in the same way with test acid. Bring the engraved line of each float on a level with the top line on the burette, by opening the pinchcock and letting any excess of solution drop into V.

> NOTE.—*The burettes must be kept dry outside; if any solution flow over when charging them, they must be carefully wiped.*

115.—Place a perfectly clean glass beaker, or a small flask, below the burette B, and let fall into the vessel exactly 15 septems of acid solution, which colour with two or three drops of tincture of logwood. Into the same vessel let fall from A, sufficient of the ammonia solution to change the colour of the liquid from yellow to pink. The last additions must be made in single drops, and the mixture shaken between each addition, or stirred with a glass rod. If more or less than 100 septems of the ammonia solution be required to neutralise 25 septems of the test acid, "small additional quantities of water or of strong ammonia

" solution must be added [to the solution in the deci-
" gallon mixer or jar], and fresh trials made, until
" the proper strength has been attained. The bottles
" in which the solution is stored should be filled nearly
" full, well stopped, and labelled."

116.—Ammonia Apparatus. The Saturator (100), as shown at S, fig. 15, is a glass vessel filled with glass beads, and it has a moveable nosepiece at N, and a glass cock at C. It is supported in a perfectly horizontal position upon a stand.

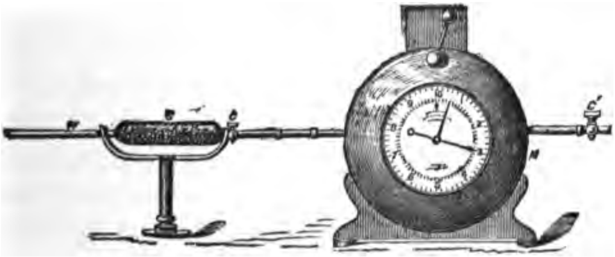

Fig. 15.

117.—The meter employed, like that described in par. 22, indicates the hourly rate of consumption by observations of a minute's duration, but its index registers up to 10 cubic feet, and it is in addition capable of automatically stopping the flow of gas when the long pointer reaches the figure 10. Two dry governors are fitted into a box on the top of the meter, the outlet of which is connected by means of a bent pipe (furnished with a vent cock) to the inlet of the first governor, which is loaded with a fixed weight, and delivers the passing gas to the inlet of the second governor, which carries a small pan, in which small weights or shot are placed to give the needful pressure for the delivery of the gas at the rate required. The adjustment of the rate may be also partly effected by means of the cock (C′, fig. 15), which may be provided with a micrometer. The stopping action consists of a cock and lever, the first being *within*, and the latter extending from the plug of the cock to the outside of the meter case, and there terminating with a ball. When nearly upright, the lever is kept up by a catch behind the index, and the cock in connection is then open, but when the long pointer reaches the figure 10 on the dial, the catch is lifted, the lever falls, and thereby closes the cock and stops the flow of the gas. A small bolt is also provided on the top of the meter, to keep the lever from falling during adjustment of rate.

118.—SULPHUR. Various apparatuses have been invented and employed in which to burn the gas, and to condense and collect the products of combustion [102(2)].

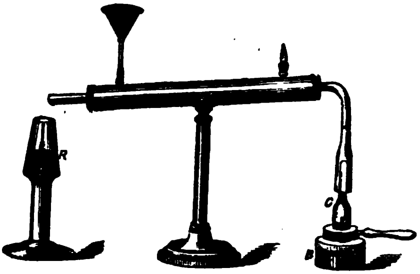

Fig. 16.

Those most employed are represented in figs. 16, 17, and 18. Fig. 16 represents the original instrument devised and introduced by the late Mr. Alex. Wright—fig. 17, Dr. Letheby's instrument—and fig. 18, the Referees' apparatus, which is now used in London. Fig. 19 is an admirable apparatus, proposed by W. Valentin, Esq., of the Royal College of Chemistry, but which has not yet been much applied in commercial testing.

119.—The analysis of the products arising from the combustion of equal volumes of the same gas in these several instruments, indicates different quantities of sulphur in the gas. The products from Wright's

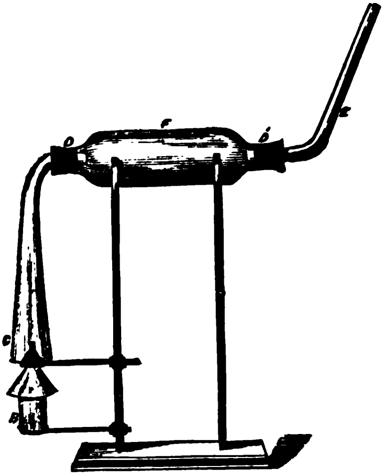

Fig. 17.

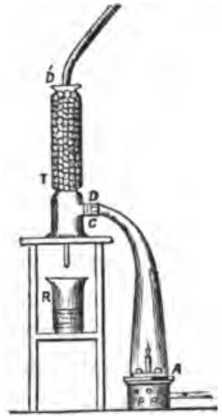

Fig. 18.

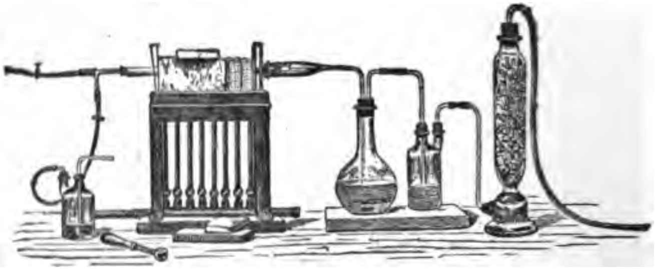

Fig. 19.

indicate the least quantity, from Dr. Letheby's and the Referees' apparatus more than those from Wright's, while it is supposed that the products from Mr. Valentin's apparatus indicate the entire quantity of sulphur contained in the gas burned.

120.—In order to obtain results with each instrument which shall be comparable and exact as possible, it is indispensable that the gas be burned at a uniform rate on all occasions, that the flames be steady, that the products be condensed under the same temperature, that no sulphur vapours be produced in the room by the ignition of lucifer matches, etc., and that any gas flames which may be employed for lighting shall be ventilated—that is, have the products of their combustion conveyed out of the room as fast as they are produced. The Gas Referees indeed say, "*the testing* "*shall be made in a room where no gas is burnt other* "*than that which is being tested for sulphur and am*-"*monia.*"

121.—Wright's apparatus (fig. 16) is a modification of the Liebeg condenser. The vessel B is to be charged with 2 oz. of strong *fresh* ammonia, and the gas burned from the jet burner within the chimney C a the rate of half a cubic foot per hour. A gentle stream of water is generally allowed to flow through the condenser so as to maintain the temperature at 80° to 90°. The condensed products are collected in the beaker, R.

122.—With the Letheby apparatus (fig. 17), the same quantity of ammonia as above stated is put into the wide-mouthed bottle B, which is covered by an inverted funnel, to which is attached a small wrought iron tube, the end of which should project one inch above the top of the burner. The condensible products are collected in the glass vessel, F. The gas in this instrument is generally burned at the rate of one cubic foot per hour.

123.—The Referees' apparatus (fig. 18) consists of a small Bunsen burner with a steatite top, which is mounted on a short cylindrical stand, A, perforated with holes for the admission of air, and having on its upper surface a deep circular channel to receive the wide end of a glass trumpet-tube. On the top of the stand, between the narrow stem of the burner and the surrounding trumpet-tube, C, are placed pieces of commercial sesqui-carbonate of ammonia, weighing in all about two ounces.*

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* Much of the sesqui-carbonate sold contains bi-carbonate of ammonia, and the excess of CO_2 materially interferes with the conden-

The products both of the combustion of the gas and of the gradual volatilisation of the ammonia salt go upwards through the trumpet-tube into the vertical glass vessel, T, packed with balls of glass, to break up the current and promote condensation. From the top of the cylinder there proceeds a long glass pipe or chimney, D, serving to effect some further condensation, as well as to regulate the draught and afford an exit for the uncondensable gases. In the bottom of the cylinder is fixed a small glass tube, through which the liquid, formed during the testing, drops into a beaker, R, placed beneath. The further instructions relating to this apparatus are as follows:—

> See that the inlet-pipe fits gastight into the burner [at A], and that the holes in the circular stand are clear. If the burner gives a luminous flame, remove the top piece, and, having hammered down gently the nozzle of soft metal, perforate it afresh, making as small a hole as will give passage to half a cubic foot of gas per hour at a convenient pressure.
>
> See that the tubulure [D] of the condenser [T] has an internal diameter of not less than $\frac{3}{4}$-inch, and that its outside is smooth and of the same size as the small end [C] of the trumpet tube.
>
> See that the short piece of india-rubber pipe fits tightly both to the trumpet-tube and to the tubulure of the condenser [C, D].
>
> The small tube at the bottom of the condenser should have its lower end contracted, so that, when in use, it may be closed by a drop of water.

---

sation of the sulphur acids. However, two or three pieces of the carbonate, each about the size of a marble, placed on the top of the balls in the condenser T (fig. 18) will, according to Mr. Heisch's experience, induce proper condensation.

The india-rubber pipe at the lower end of the chimney-tube should fit into, and not simply rest upon, the mouth of the condenser, and the upper extremity of this tube may, with advantage, be given a downward curvature.

124.—Valentin's apparatus (fig. 19) is not in ordinary use, and it will therefore be sufficient to say that it consists of a platinum or porcelain combustion tube, a gas furnace, the vessels shown in the woodcut, and an aspirator. The platinum combustion tube is filled partly with a platinum-wire cage, charged with spongy platinum and partly with soda lime (made by slacking pure lime with a solution in distilled water of pure caustic soda). The tube is then placed in the gas furnace, and maintained at a high temperature, while a measured volume of gas mixed with a due proportion of air, is sucked, as it were, by means of the aspirator, through the combustion tube. The mixture of gas and air burns when in contact with the spongy platinum, and the products pass through the soda-lime, which absorbs all the sulphuric acid generated by the combustion of the sulphur in the gas. The porcelain tube contains only a cage of spongy platinum, the products being drawn through a solution of soda-lime contained in a glass flask, whereby the sulphuric acid is absorbed. The soda-lime used in the platinum tube is taken out and dissolved in dilute hydrochloric acid, or, if the porcelain tube be used, the soda-lime solution is acidulated with dilute hydrochloric acid. The after processes are similar to those which are hereinafter described.

Fitting Up.

125.—The bench or table upon which the instruments are to rest, must be level and firm, and not be subject to vibrations. The room (or a chamber which may be formed by dividing off a part of the photometer room by a glazed enclosure) should be as large as possible, freely ventilated, and have no gas burning within it save that below the sulphur test.*

126.—If the tests are to be made in the same way as in London, fix the test glass (99) upon a stand at any convenient position on the bench, connect a metal gas-service pipe to its inlet-pipe, connect its outlet (which should, like the inlet, be below the test-glass) to the saturator S., fig. 15, by a short piece of *red* or *black*, but not grey, india-rubber tube. Complete the connections by short pieces of the same kind of tube from the outlet of the saturator to the inlet of the meter, and from the outlet of the latter (C, fig. 15) to the burner of the sulphur test. Charge the meter with water in the same way as directed, for the meter par. 29, taking care that it and all the instruments stand perfectly level. Close the cock, C, fig. 15. Turn on the gas and let it escape from the vent-cock of the meter for five or six minutes, then close the cock and try all junctions for soundness, which must be *absolute*.

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* If the room be freely ventilated, and but little gas burned within it, this refinement may in many cases be neglected.

To set the Apparatus at Work.

127.—Suspend slips of acetate of lead paper in the sulphuretted hydrogen test-glass (99).

128.—Remove the saturator S, fig. 15, from its stand, take out the nosepiece N, and close the glass cock. Remove also the glass tube from above the sulphur test burner. Charge the saturator from the burette B, fig. 13, or from a pipette with "50 septems " of the test acid (which is greatly in excess of any " quantity of ammonia likely to be found in the gas,* " so as to well wet the whole interior surface, and " also the glass beads. Any ammonia that is in the " gas will [in its passage through the vessel] be " arrested by the sulphuric acid, and a portion of the " acid (varying with the quantity of ammonia in the " gas) will thereby be neutralised."

129.—Replace the saturator on its stand, and reconnect it with the gas supply and the meter. Charge the vessel (B), if Wrights or Lethebys, with ammonia (121, 122), or if the Referee's instrument be used, place about 2 oz. of fresh sesqui-carbonate of ammonia around the burner (123).

130.—Turn back the index pointers of the meter until both are upright, and the stopping lever is held up by the catch. Pull forward the bolt (117), turn on the gas, light the sulphur test burner, replace trumpet or other tube, and promptly re-connect with the condenser. Turn the lever of the meter (which will probably have been freed from the catch) to the left, and then push back the bolt. See that the gas is burning at the required rate per hour.

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* Unless the gas contains more than about 6 grains of ammonia in 100 c. ft. In such case the acid used must be stronger, or two saturators in line be employed.

> NOTE.—When first starting, the adjustment may be conveniently made by charging the saturator with 50 septems of water, then weighting the second governor on the meter, and regulating the delivery cock until the gas burns at the proper rate. When this is effected, remove and drain the saturator, wash well with distilled water, drain as thoroughly as possible, charge with test acid, and set the apparatus going. Also it is well to provide means whereby to deliver gas direct from the service pipe to the meter, so that air may be quickly swept out of it through its vent-cock.

ANALYSIS.

131.—AMMONIA. "At the end of each period of "testing [when 10 cubic feet of gas have traversed "the saturator],* the glass cylinder and its contents "are to be well washed out with distilled water, and "the washings collected in a glass vessel. One half "of the liquid is to be taken in a separate glass ves-

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* If it be desired that the meter should stop when a smaller volume, say 5 c. ft., of gas has passed, set the long pointer at the fig. 5 on the dial when starting the test.

"sel, and a quantity of solution of hæmatoxlylin* "(which is turned pink by alkalies) added just suffi- "cient to cause the liquid to assume a yellowish "colour. Then pour into the burette 100 septems of "the test alkali, and gradually drop this solution into "the measured quantity of the washings collected, "stirring constantly: as soon as the colour changes to "a pink tint, which remains permanent for five min- "utes (indicating that the whole of the sulphuric acid "has been neutralised), read off the quantity of liquid "remaining in the burette."

132.—"To find the number of grains of ammonia in "100 cubic feet of the gas, multiply by 2 the number "of septems of test alkali remaining in the burette, "and move the decimal point one place to the left." *Ex.*, Liquid remaining in the burette 13·4 × 2 = 26·8, decimal point moved one place to the left = 2·68 grains per 100 cubic feet in the gas. "The remaining "half of the liquid is to be preserved in a bottle duly "labelled for a week."

133.—SULPHUR. "At the end of each period of "testing, the cylinder and trumpet-tube are to be "well washed out with distilled water." This instruction applies also to the Letheby apparatus. "Fresh "pieces of sesqui-carbonate of ammonia are to be used "each day," *i.e.*, for each testing.

134.—The condensed liquid resulting from the combustion of gas in any of the four instruments mentioned must then be treated in the manner directed by the Referees, which is as follows :—

---

* Tincture of logwood.

“The liquid in the beaker and the water used in “ washing out the apparatus shall be put into the same “ vessel, well mixed and measured. One-half of the “ liquid so obtained is to be set aside and preserved “ for a week, properly labelled, in case it should be “ desirable to verify the correctness of the testing.”

135.—“ The remaining half of the liquor is to be put “ into a beaker [fig. 20], “ covered with a large “ watch-glass . . treated “ with hydrochloric acid “ sufficient in quantity to “ leave an excess of acid in “ the solution . . . , and “ then raised to the boiling “ point, but not so violently “ as to occasion loss by “ spirting.” The hydrochloric acid should be used in a diluted condition—one part strong acid to 4 or 5 parts of water. The presence of an excess of acid in the liquid will be shown by the complete absence of effervescence in the last additions, and by the application of a litmus test

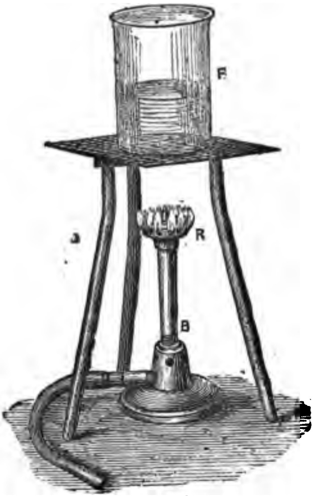

Fig. 20.

paper, which will change colour from blue to a distinct red colour.

136.—"An excess of a solution of barium chloride "is now to be added, and the liquid again boiled for "five minutes." The solution of barium chloride consists simply of the chloride dissolved in distilled water in the proportion of about 10 grains of chloride to the ounce of water. A little experience will soon satisfy the operator in respect to *an excess.*

"The vessel and its contents are to be allowed to "stand till the barium sulphate settles at the bottom "of the vessel, after which the clear liquid is to be, "as far as possible, poured off through a filter paper. "The remaining liquid and barium sulphate are then "to be poured on to the filter, and well washed with "hot distilled water." The paper must be free from impurities, and a piece, about 4 inches diameter, when burned by itself in crucible G, Fig. 26, to whiteness, should not produce more than 4-100ths of a grain of ash.

137.—To form the filter, "Take a circular piece of "filtering paper, fold it in half, and then again at "right angles at the first fold, so "that the circle is reduced to a "quarter circle, consisting of four "thicknesses of paper. Open this "out, so as to form a conical "cavity, fig. 21, having three folds "of the paper on one side and one on the other; and

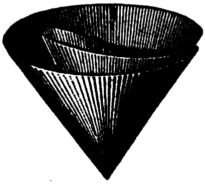

Fig. 21.

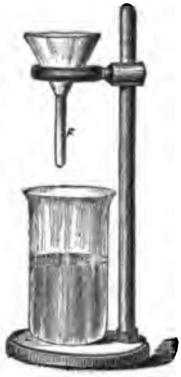

Fig. 22.

" place it in a funnel slightly larger than " the filter thus folded [fig. 22]. The filter should fit the funnel pretty accurately, and may require to be " opened out a little more, or, on the " other hand, contracted so as to form " a more acute cone; but in all cases " care should be taken not to injure " the point, which, although it requires most strength, is generally " the weakest part, since all the " creases meet there." *

138.—The filter should be first wetted with distilled water delivered from a wash-bottle, and " certain precautions are required in " transferring a solution to " a filter, in order to avoid " loss. A glass rod should " be moistened with distilled water, and brought " against the edge of the " vessel from which the " liquid is to be poured, " fig. 23. By this means, when the pouring is ended, " if the rod be still kept in contact with the edge, the " last drop is prevented from running down the outside of the vessel. After the whole of the liquid

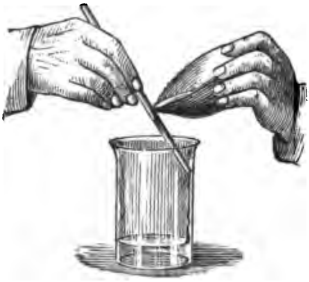

Fig. 23.

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* " Exercises in Practical Chemistry," by A. G. Vernon Harcourt, M.A., F.R.S., &c., and H. G. Madan, M.A., F.C.S.

" has been poured off, the portion which adheres to " the rod and to the sides of the vessel, is washed " down by a jet of water from a washing-bottle, fig. 24, " and the washings are added to the rest of the de- " canted liquid.—(Miller.)

139.—The washing of the filter is effected by applying the lips to the pipe, T, of the wash-bottle, fig. 24, and blowing a gentle stream of hot water from the pipe, O, upon the filter. In washing a precipitate in a filter, fig. 22, the stream of water should be directed upon the upper edge, so as to wash down the particles, which have a tendency to accumulate there as the solution rises under the influence of capillary action. " In order to ascertain " whether every trace of barium " chloride and ammonium chloride has been removed, " a small quantity of the [latest] washings from the " filter should be [received direct from the funnel] " in a test-tube, and a drop of a solution of silver " nitrate or dilute sulphuric acid added; should the " liquid, instead of remaining permanently clear, become " cloudy, the washing must be continued until on " repeating the test no cloudiness is produced." The silver solution is made with silver nitrate dissolved in pure distilled water, in about the proportions

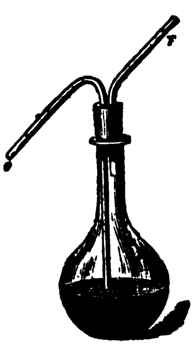

Fig. 24.

"between 955-965, 966-975, 976-985, 986-995; increase the number of grains of sulphur by 4-100ths, 3-100ths, 2-100ths, 1-100th of the weight found.

"When the Tabular Number is between 996-1005, no correction need be made.

"When the Tabular Number is between 1006-1015, 1016-1025, 1026-1035, diminish the number of grains of sulphur by 1-100th, 2-100ths, 3-100ths.

Ex.:—

Grains of barium sulphate from 5 cub. ft.
of gas . . . . 4·3

Multiplied by 11 and divided by 4 = grains
of sulphur in 100 cub. ft. of gas
(uncorrected), or, ...11·82 grs.
Barometer (mean) . 29·2
Thermometer (mean) 54
Tabular Number . 985
Add 2-100ths of 11·82 grains = . . . ·24

Grains of sulphur in 100 cub. ft. of gas
(corrected) . . . . .12·06

144.—If a dessicator be used for the purpose mentioned in the preceding paragraph, it may consist of of a small porcelain pan, having a few upright partitions in it, to support the crucible and a bell cover. Strong sulphuric acid is then poured in the crucible placed upon the top of the partitions, and the pan

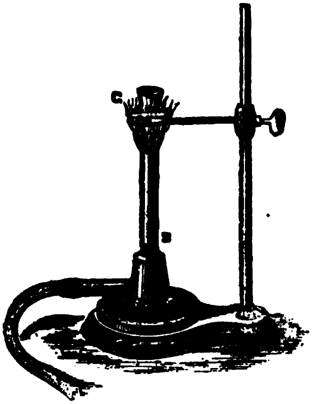

Fig. 26.

"redness. When no "black particles remain, "allow the crucible to "cool; place it when "nearly cold in a dessi"cator over strong sul"phuric acid (to prevent "absorption of mois"ture), * and again "weigh. The difference "between the first and "second weighings of "the crucible will give "the number of grains of barium sulphate. Multiply "this number by 11 and divide by 4, the result is the "number of grains of sulphur in 100 cubic feet of the "gas."

143.—"This number is to be corrected for the va"riations of temperature and atmospheric pressure, " . . the readings of the barometer and thermo"meter are to be taken for the day on which the test"ing commenced, and also the day on which it closed, "and the mean of the two is to be used.

"This correction may be made most simply, and "with sufficient accuracy, in the following manner:—

"When the Tabular Number [Appendix C] is

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* The usual way is to cool the crucible quickly by placing it on a block of iron, and at once weighing. No sensible error can arise from this procedure.

salts uniting with the *barium* of the *chloride* to form *barium carbonate* and *barium sulphate,* while the *chlorine* of the barium chloride unites with the *ammonium* (H_4 N) of the ammonium carbonate and sulphate to form soluble *ammonium chloride.* In order to avoid the precipitation of *barium carbonate* with the *barium sulphate,* the liquid is acidulated with hydrochloric acid, and boiled, so as to drive off all carbonic acid and completely unite the ammonium which at first was in solution as a *carbonate* with the hydrogen acid, so as to form the other soluble salt, ammonium chloride. Finally, the barium solution is used to decompose the ammonium sulphate, and give a precipitate of insoluble barium sulphate.

148.—All the chemicals employed must be of the purest description. If it is deemed needful to test any samples, the requisite information will be found in chemical text books.

SECTION III.

IMPURITY TESTS AND PRACTICAL ANALYSIS OF COAL-GAS.

149.—Ammonia. Is detected by exposing a test paper imbued with a tincture of turmeric to a jet of the gas. In the presence of ammonia the colour of the paper will change to a brownish tint, tending towards a strong red if much of the impurity be present. The presence of so small a quantity as about one grain of ammonia in 100 cubic feet of gas, will induce change in the colour of the test paper. The papers should be a full yellow, but not tending too much towards orange, and be of the best quality. The tincture to give a sensitive paper should be made by infusing turmeric in pure spirits of wine. When clear, the coloured spirit is decanted, and slips of blotting paper immersed, which are afterwards dried in a pure atmosphere.

150.—Sulphuretted Hydrogen. Tested by acetate of lead paper, as mentioned in par. 99.

151.—Carbonic Acid. A clear solution of caustic lime, or, better, of barium chloride is made, the first by adding some caustic lime to clean water, shaking up and decanting when clear, and the latter by adding the chloride in the proportion of about 10 grains to the ounce of distilled water. Both solutions must be kept in closely stoppered bottles. For the test, about an ounce of liquid is taken in a test tube, and a small glass tube or pipette, which is connected by means of rubber tube to a gas cock, dipped into the liquid, and the gas allowed to bubble through until the maximum degree of milkness is produced by the formation of insoluble carbonate of calcium or of barium.

The Cooper's Tube, or Eudiometer.

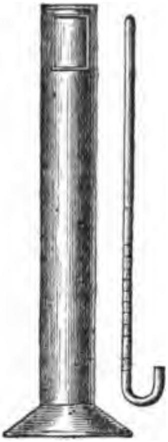

Fig. 27.

152.—This is a useful instrument for ascertaining approximatively the composition of any sample of coal gas. As originally made for Mr. Lewis Thompson, it is a glass tube about ⅝-inch diameter and 30 inches long, sealed at one end and bent at the other. About 1½ inches above the bend a mark is made, and the space between that point and the sealed end is graduated into 100 parts,* and each of these again subdivided into 5 parts, so that each large division is *one* per cent., and each small division *two-tenths* per cent. of the space divided. With this tube a metal cylinder with a glass top is used; this is called the "equaliser." The tube and cylinder are shown in fig. 27.

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* As the extension of the divisions over the whole length serves no useful purpose, the graduations are limited to *one-fourth* the space, *i.e.*, 25 per cent. of the capacity.

153.—In order to shorten the tube while retaining its capacity, it is now frequently made with a globe top, or bulb—the tube itself still being divided to indicate 25 per cent. of the whole contents of the tube. With such tubes, which are about 15 inches long, a cylindrical glass vessel is employed instead of the cylinder of metal.

154.—The mode of using the apparatus is the same in all cases, whatever be the matter sought, the only difference being in the absorbing substances applied. Charge the "equaliser" with clean water to within about two inches of its top. Take the tube in the left hand, the open part of the bend being upwards, and the closed end inclined at a convenient angle towards the ground. Pour in clean water until the tube is full, then close the open end with the thumb or stopper, and hold the tube vertically with the bend upwards for about a minute, so that all air bubbles may rise to the bend. Turn the tube so as to pass the air over to the thumb (fig. 28), which remove to permit any air to escape, and dip the bend into clean water contained in a dish or bowl, about 8 or 10 ins. diameter, and deep enough for the complete immersion of the bend. Insert a piece of ⅛-inch india-rubber

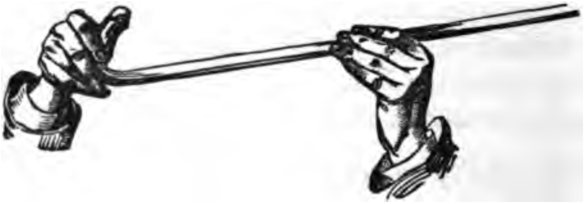

Fig. 28.

pipe, from which the gas is freely issuing, into the open end and round the bend of the tube. Then, still keeping the open end below the water, raise the tube into such a position as is shown in fig. 29. Let the gas flow in until it reaches a little below the zero line. Remove the rubber pipe, and immerse the tube downwards in the water of the "equaliser," taking care in doing this that the bend is kept sealed with water, and that no gas escapes or air enters.

155.—After the lapse of two or three minutes, raise the tube sufficiently to bring the water-line within it level with that in the "equaliser." If the water-level be above the zero, more gas must be added, or the results corrected for volume by calculation; if too much gas be contained, the excess may be got rid of by closing the end of the tube tightly with the thumb, and allowing small bubbles to pass over (fig. 28), then to escape, taking care to fill up the tube with water after each removal of the thumb, and also that no air enters. Re-immerse in the "equaliser," and so on, until the tube is properly charged. As a contraction in volume is almost certain to succeed the immersion, it is well to charge the tube at first to a little below the zero line.

156.—Another way of filling the tube, which is preferred by some operators is to project the rubber pipe nearly or quite to the top of the tube while the latter is in a dry state, and to blow gas through for some minutes to expel the air, then to immerse the bend under water, remove the rubber tube, and to proceed as above stated. The notion is, that by this method the water is less likely to absorb any of the constituents of the gas, but the Author thinks that the practical difference in effect is *nil*, as mere surface contact of clean water with gas will cause some absorption of carbonic acid and ammonia, and much more than such contact arises during the adjustment of the contained volume. In these truths lies much of the imperfection ef the analyses made with the Cooper's Tube.

157.—CARBONIC ACID. Charge the tube with purified gas in the way directed (154). Drop into the bend a piece of pure caustic potash about the size of a pea.

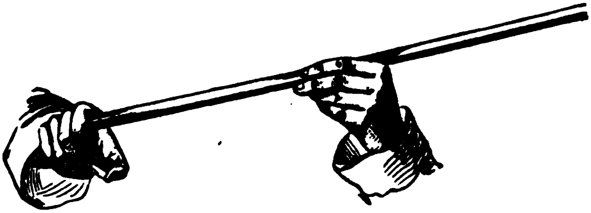

Fig. 29.

Close the tube with the thumb, excluding all air, which will form a little bubble under the thumb (unless the bend is *quite* full of water), and gently shake the tube, then turn it over to the position shown in fig. 29, so as to pass the whole of the gas into the long leg of the tube. Immerse the tube in the "equaliser," and after two or three minutes raise into an upright position (155) and observe the absorption due to $C\,O_2$.

158.—HYDRO-CARBONS. Bromine was introduced by Mr. Lewis Thompson for the absorption of these compounds in coal-gas. The sample of gas which has been operated on for $C\,O_2$ is tested. A drop of bromine, about the size of a pea, is taken in a small pipette, fig. 30, by dipping its end into the bromine, pressing on the top, and then transferred to the tube; or a strong solution of bromine (made by adding bromine to distilled water) may be used, if so, remove part of the water from the bend of the tube, taking care not to unseal, and fill up with the solution.

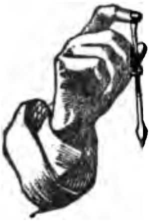

Fig. 30.

159.—When shaken, the tube should be filled with red vapours, showing an excess of bromine. If too much bromine be used, the volume of the gas, instead of being reduced, may be so much increased by the vapours, that the water in the bend may be blown out on removing the thumb, and the experiment spoiled.*

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* With attendant risk to the operator, as bromine is dangerous when inhaled, and as it is also corrosive on the skin, it must be used with caution.

160.—In rich gases the contraction is considerable, and the tube must be opened *under water,* as indeed it is best always to do, with the bend turned down.

161.—The tube should then rest within the "equaliser" for five minutes. If the red vapours are then still visible, enough bromine has been used. Now add a piece of caustic potash, or some strong solution of the same, shake the tube again; all red vapours should disappear, if not, add potash and shake gently until the tube is clear. Immerse for ten minutes in the equaliser and then raise (155), find the reduction in volume in excess of that found for CO_2, which excess represents the percentage volume of illuminating hydro-carbons.

162.—CARBONIC OXIDE. This is but a doubtful test with the Cooper's tube. It is made upon the gas after the absorption of the hydro-carbons, and in order to clear the tube of deposited matter, it is inclined as in fig. 29, with the open end immersed in clean water. In a minute or two the water and condensed matters will be replaced by clean water. Pour into the tube a solution of sub-chloride of copper in hydrochloric acid, and shake the tube a few times to and fro; replace the water in the tube by immersion in the way above described. Add potash to remove acid vapours. Equalise the temperature, and read off the percentage absorption of CO.

163.—The solution of sub-chloride is made by adding hydrochloric acid to black oxide of copper, and inserting some metallic copper. Keep in a stoppered bottle. It is said to absorb olefiant gas and oxygen as well as CO, but not to act upon hydro-carbon vapours, or the other constituents of coal-gas.

164.—SULPHURETTED HYDROGEN. Should not be present in purified gas, but may be estimated in foul gas by means of acetate of lead, or a weak solution of sulphate of copper. Equalise, note absorption, clear the tube of fouled water, and then add potash to find CO_2. Ammonia may also be first sought with *dilute* sulphuric acid, but the experiment is doubtful. It is however advisable to acidulate the water with the acid named before testing for H_2S, to avoid the indication of an excess of the latter.

165.—The amount of carbonic acid and of sulphuretted hydrogen in crude gas, may also be estimated in the following manner—two experiments being necessary.*

166.—CO_2 AND H_2S. Pass the gas at the rate of half to three-quarters of a cubic foot per hour through a small "scrubber," S, or box filled with fragments of dry coke (in order to remove any tar), thence through a series of U tubes, as shown in fig. 31, and finally through an experimental meter.

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* Kindly furnished, with the exception of the rules and gravities, by Mr. F. D. Marshall, Gas Works, Brentford.

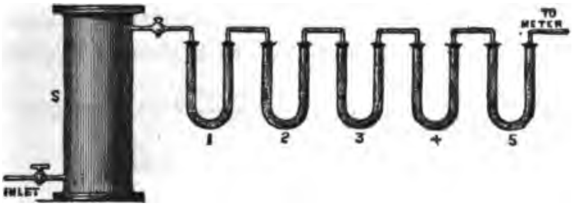

Fig. 31.

167.—The tubes may be about three inches long and half-an-inch internal diameter. The connections are made with reed tubes, as shown, and with accurately fitting india-rubber stoppers (or preferably good corks coated with paraffin wax). The tubes (Nos. 1 and 2) are filled with fragments of dry calcium chloride to absorb moisture, the two next with fragments of soda-lime, while the first limb and three-fourths of the second limb of the last tube (No. 5) are charged with dry calcium chloride, and the remainder of the second limb charged with soda-lime. This tube guards the soda-lime tubes, and prevents the introduction of any moisture or CO_2 from the atmosphere.

168.—At the commencement of the experiment, the two tubes, 3 and 4, containing soda-lime are accurately weighed, and also after five or ten cubic feet of gas have been passed through. The increase in weight is due to the absorption of CO_2 and H_2S.

169.—To Estimate H_2S only. The gas is first passed through the "scrubber" S, as before, then through the arrangement shown in fig. 32. and thence through the meter The flask, A, contains solution of caustic soda, B is a tube filled with glass beads, which

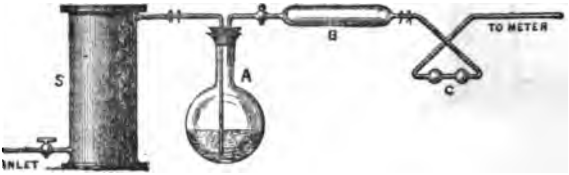

Fig. 32.

are moistened with caustic soda solution, while C is a bulb tube to catch any liquid carried forward from A and B.

170.—After the passage of five or ten cubic feet of gas, wash the contents of the vessels out into a large beaker. Add solution of arsenite of soda, and then add sufficient hydrochloric acid to produce a strongly acid reaction, which may be ascertained by the decided reddening of a blue litmus paper dipped into the liquid. The sulphur of the sulphuretted hydrogen will be precipitated as trisulphate of arsenic, $As\,S_3 = 123$. Filter, well wash, and dry over a water-bath at 212° Fahr. Every 100 grains contain 39·02 grains of sulphur, which, when combined with hydrogen as $H_2\,S$, in the proportion of 16 to 1, would give 41·34 grains for the weight of $H_2\,S$ acted upon, or 4·18 per cent. very nearly, greater than the sulphur indicated.

171.—One cubic foot of dry air, weighing 535·9 grains (221), and the specific gravity of $H_2\,S$ being 1 174 (Miller), one cubic foot of the latter must weigh

630·39 grains,* and a cubic inch ·36408 of a grain. By dividing unity by these numbers, multipliers are obtained for volume in cubic feet and cubic inches, viz., ·0015863 for cubic feet and 2·747 or 2·748 for cubic inches.

To calculate weight of Sulphur.

172.—Multiply the number of grains of trisulphate of arsenic obtained by ·3902, and divide by the number of cubic feet operated upon.

Ex.	Grains obtained . . .	100
	Multiplied by	·3902
	Weight sulphur . . .	39·02
	Add 4·18 per cent . . .	1·63
	Weight H_2S, 10 cubic feet	40·65 grains.

or 4·065 grs. per c. ft.

To find Volume H_2S in 100 cubic feet of Gas.

173.—Multiply weight last obtained by ·15863, and divide the sum by the number of cubic feet of gas operated upon.

Ex. . . 40·65 X ·15863 = 6·554

Divided by cubic feet say 10

Vol. H_2S in 100 c. ft. or ·6554 of a c. foot.

---

* Miller says that 100 cubic inches weigh, at 60° or 30°, "a little more than 88 grains," or more than ·38 of a grain per cubic inch, but such weight is inconsistent with the gravity given.

174.—The volume of gas operated upon must be corrected by multiplying it by 1000 and dividing by the tabular number (Table C, Appendix) corresponding to the temperature and pressure.

175.—The weight of sulphuretted hydrogen, found by the first rule (172), subtracted from the weight obtained in the first experiment, leaves a remainder equal to the weight of CO_2.

176.—103 cubic inches of CO_2 weigh, at 60° and 30 inches, 47·3 grains (Miller), therefore one cubic foot must weigh 817·344 grains, and unity divided by that number gives the multiplier ·00122347 for one foot and ·122347 for 100 cubic feet of gas.

Rule to find the Volume CO_2 in 100 cubic feet of Gas.

177.—Multiply the weight in grains of CO_2 found by ·122347, and divide by the number of cubic feet operated upon.

Ex.: Grains found . . 164·
Multiplied by . . ·122347

Divided by cub. ft. used = 10)20·06490

CO_2 in 100 cub. ft. gas . . . 2·065 cub. ft.

178.—By the processes described, it is said that very exact results are obtained; but it must be remembered that as the gas is measured *after* the removal of the H_2S and CO_2, the original volume must in all cases be greater than that measured. Thus, taking the volumes as above at 100 cubic feet measured, the original volume must have been—

Gas measured . . .	100	cubic feet.
H_2S	·655	,,
CO_2	2·065	,,
	102·720	

So that the true percentages by volume of the impurities become ·655 × 100 ÷ 102·720 and 2·065 × 100 ÷ 102·7 or ·637 and 2·01 per cent.

Harcourt's Colour Test.

179.—This is an extremely valuable apparatus for the gas-maker, as by its aid the amount of carbon bisulphide, sulphuretted hydrogen, and carbonic acid in purified gas may be expeditiously estimated, and the efficiency of the purifying processes ascertained within less than half-an-hour.

180.—CARBON BISULPHIDE. The arrangement of the colour test is shown on the next page, fig. 33, the lower part of which is cut away to suit the size of the page, the chimney of the burner being represented by dotted lines. The bulb, which is filled with platinised pumice, is to be so adjusted that it may be about an inch above the burner and in the middle of the cylinder.

181.—To use the apparatus, turn on first the upper stopcock, sending gas through the bulb at the rate of about half a cubic foot an hour, as may be judged by lighting the gas for a moment at the end of the horizontal arm, when a flame about an inch in length

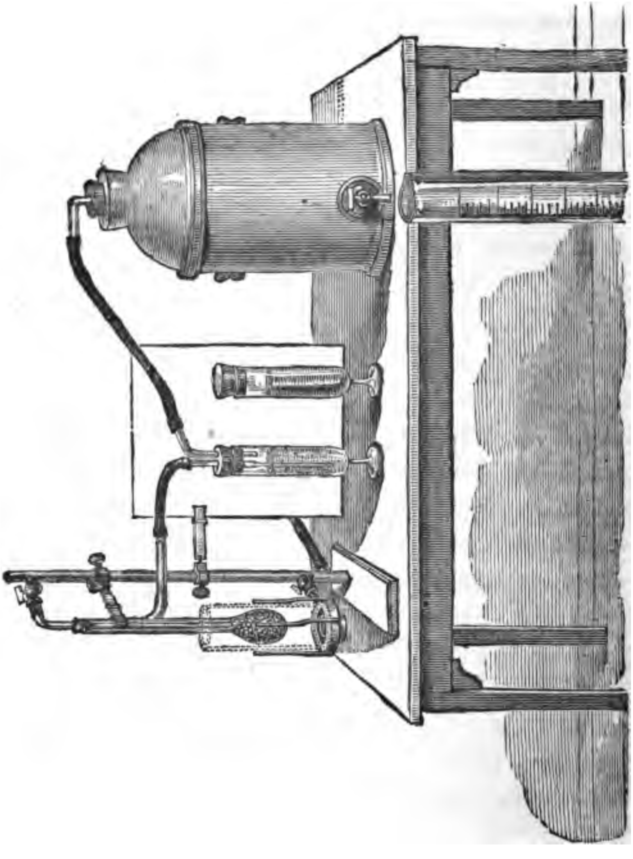

Fig. 33.

should be produced. Raise the cylinder, which will be supported by the pressure of the wires, light the burner, and turn down the flame till it forms a *blue, non-luminous ring*. Lower the cylinder, and place the small clay-pieces upon it round the neck of the bulb.

182.—A testing may be made five minutes after the burner is lit, except when the apparatus is first used, when the gas should be allowed to flow through the bulb for a quarter of an hour, or a little longer, and any number of testings may be made one after another, as long as the heat is continued.

183.—The mode of testing is as follows. Lay a piece of white paper on the table, by the side of the burner, and fix a piece of cardboard upright in the brass clip; the cardboard serves as a background against which to observe the colour of the contents of the glasses, and should receive a side light, and be as clear as possible from shadows. Fill one glass (once for all) up to the mark with standard coloured liquid, and cork it tightly.* Dilute some of the lead syrup with about twenty times its volume of distilled water, and fill the other glass up to the mark with a portion of the liquid thus prepared. Insert the caoutchouc plug with capillary-tube and elbow tube,† and connect, as shown in the print, with the bulb and aspirator, placing the two glasses side by side.

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* There are *two* standard colour solutions, one for daylight and the other for gaslight, and these are now sent out in sealed glasses. The glass containing the standard should be shaken before commencing a test.

† The capillary-tube should descend very nearly to the bottom of the glass, but must not press upon the bottom, or it will probably be broken.

184.—The aspirator should be full of water at starting, and the measuring cylinder empty. Turn the tap of the aspirator gradually; a stream of bubbles will rise through the solution of lead. Turn off the tap for a minute, and observe the liquid at the bottom of the capillary-tube. If it gradually rises, the india-rubber connections are not air-tight, and must be made so before proceeding. *Avoid pressing the plugs into the glass or the aspirator while they are connected,* which would drive up the lead solution into the inlet tube. When the connections are air-tight, let the water run into the measuring cylinder in *a slender stream* until the lead solution has become as dark as the standard. As the ascending bubbles interfere somewhat with the observation of the tint, it is best to turn off the tap when the colour seems almost deep enough; compare the two; turn on the tap, if necessary, for a few moments; then compare again; and so on, till the colour of the two liquids is the same.

185.—The volume of water which the measuring cylinder now contains is equal to the volume of gas which has passed through the lead solution.

186.—This volume of gas contained a quantity of sulphur as carbon bisulphide, which as lead sulphide, has coloured the liquid in the test-glass up to the standard tint. The standard has been made such, that to impart this tint to this volume of liquid, 0·0187 gr. of lead sulphide must be present, containing 0·0025 gr. of sulphur. Hence, supposing the measuring cylinder, each division of which corresponds to 1-2000th of a cubic foot, to have been filled to the 30th division, 30-2000ths of a cubic foot of gas contained 0·0025 gr. of. sulphur. From this ratio the number of grains of sulphur existing as bisulphide in 100 cubic feet of the sample of gas tested can easily be calculated.

187.—The following table gives the relation between (V) the divisions of the measuring cylinder filled with water, and (S) the grains of sulphur *existing as bisulphide* in 100 cubic feet of gas. Since gas contains, besides carbon bisulphide, some other sulphur compounds which *are not transformed into sulphuretted hydrogen* by the action of heat, and which contain sulphur amounting ordinarily to *7 or 8 grains in 100 cubic feet*, this quantity *must be added* to that found by the Test, if it is wished to know approximately the *total amount of sulphur* in the gas.

TABLE I.

$$S = \frac{500}{V}$$

V	S	V	S	V	S	V	S
10	50·0	14	35·7	18	27·8	22	22·7
11	45·4	15	33·3	19	26·3	23	21·7
12	41·7	16	31·3	20	25·0	24	20·8
13	38·5	17	29·4	21	23·8	25	20·0

TABLE I.—continued.

V	S	V	S	V	S	V	S
26	19·2	45	11·1	64	7·8	83	6·0
27	18·5	46	10·9	65	7·7	84	6·0
28	17·9	47	10·6	66	7·6	85	5·9
29	17·2	48	10·4	67	7·5	86	5·8
30	16·7	49	10·2	68	7·4	87	5·7
31	16·1	50	10·0	69	7·2	88	5·7
32	15·6	51	9·8	70	7·1	89	5·6
33	15·1	52	9·6	71	7·0	90	5·6
34	14·7	53	9·4	72	6·9	91	5·5
35	14·3	54	9·2	73	6·9	92	5·4
36	13·9	55	9·1	74	6·8	93	5·4
37	13·5	56	8·9	75	6·7	94	5·3
38	13·2	57	8·8	76	6·6	95	5·3
39	12·8	58	8·6	77	6·5	96	5·2
40	12·5	59	8·5	78	6·4	97	5·2
41	12·2	60	8·3	79	6·3	98	5·1
42	11·9	61	8·2	80	6·2	99	5·1
43	11·6	62	8·1	81	6·2	100	5·0
44	11·4	63	7·9	82	6·1	150	3·3

188.—For the next testing, the test-glass is to be disconnected and re-charged. The water in the measuring cylinder is poured back into the aspirator.

189.—The colour of the standard is unaffected by exposure to light, but deepens if the liquid is warmed, returning to its original shade as the liquid cools. If, therefore, the glass containing the standard has been in a warm place, it must be let cool before testing.

190.—The liquid which has been used becomes colourless after being exposed to the light for a few hours, and may thus be used over and over again for twenty times or more, *if it is not allowed to absorb carbonic acid from the air.* The best mode of working is to have two well-corked flasks, into one of which the coloured liquid is emptied, while the glass is recharged from the other.

191.—The apparatus may also be used, without the bulb-tube and stand, to test the amount of sulphuretted hydrogen or carbonic acid in gas at any stage in its purification. The gas is led in this case directly into the test-glass, which is charged with lead solution for sulphuretted hydrogen, and with a saturated solution of barium hydrate (baryta water) for carbonic acid.

192.—$H_2 S$. When the gas contains more than 50 grains of sulphur as sulphuretted hydrogen in 100 cubic feet, a smaller cylinder, containing 1-200th of a cubic foot, is used to measure the volume of liquid run from the aspirator. The divisions on the smaller cylinder are tenths of the corresponding divisions on the larger cylinder; therefore when it is used, the numbers under S in Table I. must be read as whole numbers, by omitting the decimal point.

193.—$C O_2$. To estimate carbonic acid, a standard liquid containing a definite amount of suspended barium carbonate is used for comparison. The glasses are placed side by side on a blackened board or piece of paper and with a black background behind them. The passage of the gas should be interrupted, and the test-glass slightly shaken once or twice to wash down any particles of carbonate which may cling to the sides of the glass above the surface of the liquid.* The standard should also be shaken before the comparison is made, in order that the precipitates may be in a similar condition. When the two liquids are judged to be equally white and opaque, the volume of water in the measuring cylinder gives the volume of gas which has precipitated a known weight of barium carbonate. Table II. gives the relation between (V) the divisions of the large measuring cylinder filled with water and (C) the volume of carbonic acid in 100 volumes of gas. When the gas contains more than ·72 per cent. of carbonic acid, the smaller measuring cylinder should be used, and the values of C multiplied by moving the decimal point one place to the right.

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* The test-glass may be shaken sufficiently without disconnecting it.

TABLE II.

V	C	V	C	V	C	V	C
10	·72	33	·22	56	·13	79	·09
11	·65	34	·21	57	·13	80	·09
12	·60	35	·21	58	·12	81	·09
13	·55	36	·20	59	·12	82	·09
14	·51	37	·20	60	·12	83	·09
15	·48	38	·19	61	·12	84	·09
16	·45	39	·18	62	·11	85	·08
17	·42	40	·18	63	·11	86	·08
18	·40	41	·17	64	·11	87	·08
19	·38	42	·17	65	·11	88	·08
20	·36	43	·17	66	·11	89	·08
21	·34	44	·16	67	·11	90	·08
22	·33	45	·16	68	·11	91	·08
23	·31	46	·16	69	·10	92	·08
24	·30	47	·15	70	·10	93	·08
25	·29	48	·15	71	·10	94	·08
26	·28	49	·15	72	·10	95	·08
27	·27	50	·14	73	·10	96	·07
28	·26	51	·14	74	·10	97	·07
29	·25	52	·14	75	·10	98	·07
30	·24	53	·14	76	·09	99	·07
31	·23	54	·13	77	·09	100	·07
32	·22	55	·13	78	·09	150	·05

194.—After each testing the glass and capillary-tube should be cleaned with a little *dilute* hydrochloric acid and well rinsed with distilled water. The turbid liquid is poured into a flask, which should be kept well corked, containing an excess of crystallised barium hydrate. After the suspended precipitate has subsided, the clear liquid is poured off, or, if necesary, filtered, into another flask, also kept well corked, from which it may be poured into the test-glass when required. Care should be taken not to expose the solution to the air longer than necessary.

A Rapid and Accurate Method of Estimating Sulphur in Coal Gas.

195.—The process described in pars. 135 to 142 is attended with difficulties and takes much time, while that about to be explained, which is due to W. C. Young, Esq., F.C.S., &c., and is herein republished by his permission, takes a very short time to complete, can be readily performed, and gives, it is said, more accurate results than the ordinary process already referred to.

196.—Before proceeding to details of the method, and in order to explain its principle, it is necessary to consider the nature of the substances to be dealt with.

197.—In the liquor given by the Referees' apparatus (fig. 18, page 73), there are present carbonate of ammonium and sulphate of ammonium. Before converting the latter compound into sulphate of barium, it is necessary to decompose the former, which is effected by boiling the liquid with an excess of hydrochloric acid, chloride of barium being afterwards added. There is then present the excess of chloride of barium, hydrochloric acid, chloride of ammonium, and sulphate of barium.

198.—Now, as hydrochloric acid and chloride of ammonium are readily volatile, whereas chloride of barium is not, it follows that, if the quantity added of the latter be known, then the amount left, after volatilising the two former, must be the excess of chloride of barium added, the difference being clearly due to the chloride of barium required to decompose the sulphate of ammonium.

199.—The chlorides admit of easy estimation; indeed, the process by which it is effected is at once the most accurate and simple in the domain of volumetric analysis; so that we have in this way a ready indirect means of ascertaining the amount of sulphate of ammonium contained in the liquor given by the Gas Referees' apparatus.

200.—The apparatus is used in the ordinary way, excepting that an upright eduction-tube [D, fig. 18, page 73] 12 inches long is employed, in order that the bulk of the liquor obtained may be small. If 10 cubic feet have been burned, the liquor and washings are made up to 500 septems (half a deci-gallon), well mixed, and 25 septems (1-20th part) measured by a pipette for the experiment. To this is added a slight excess of acetic acid (two drops are generally sufficient) and 10 septems, measured by a pipette, of a standard solution of chloride of barium, containing 16·25 grains in one gallon. The whole is then transferred to a shallow flat-bottomed platinum capsule, and evaporated to dryness over a burner. The evaporation can be conducted over an Argand or rose Bunsen burner, the heat being adjusted so as to keep the liquid just below boiling, and so prevent possible spurting; but, where a number of estimations are being made simultaneously, it is best done on a water or steam bath. After evaporating to dryness, the residue is gently heated until the crucible is at a slight red heat; it is then cooled, and the contents washed out with water into a small beaker. To this solution an excess of a solution of yellow chromate of potassium is then added, and a standard solution of nitrate of silver, containing 531·2 grains per gallon, is added from a burette [similar to A or B, fig. 13, page 65] containing 50 septems (graduated into fifths of a septem), until a permanent change of tint is observable on shaking the liquid.

201.—Each septem left in the burette indicates one grain of sulphur per 100 cubic feet of gas, and each division ·2 grain.

202.—As many of those for whose benefit this process is intended may be unacquainted with the use of a standard solution of nitrate of silver for estimating chlorides, a few words explanatory of the process may not be out of place.

203.—When a solution of nitrate of silver is added to a mixture of soluble chromate and chloride, there is produced at first a deep red precipitate of chromate of silver, which is immediately converted into the white chloride of silver, the colour at once disappearing. This action goes on until the whole of the chlorides present have been precipitated, and then the deep red chromate of silver formed is unaffected, and so marked is the change in the colour, that one drop in excess of the standard solution of nitrate of silver employed in this process produces such a decided red tinge, that no one could be mistaken. This one drop would introduce an error of less than ·2 grain of sulphur per 100 cubic feet of gas.

204.—The process of evaporation, as directed, takes at the most fifteen minutes, the rest of the work needing a few moments more, and as the result must necessarily be at least as accurate as that given by the tedious gravimetric method, the process will, without doubt, commend itself to those who desire to know in a short time the sulphur contained in the gas under examination.

205.—Moreover, should the result of a test appear at all extraordinary, it can readily be checked by a repetition, or by a separate gravimetric estimation, as only a very small quantity of the liquid is used.

206.—Should the gas contain more than 50 grains of sulphur per 100 cubic feet, it will be necessary to make the bulk of the liquor up to one deci-gallon (twice the quantity before directed), proceed as usual, and multiply the number of septems of standard nitrate of silver solution remaining by two, to find the amount of sulphur present.

207.—If a "short" test is desired, one-half of a cubic foot should be burnt, when, if the whole of the liquor be taken, the number of septems of standard nitrate of silver solution remaining will indicate the number of grains of sulphur per 100 cubic feet.

Specific Gravity.

208.—A knowledge of the specific gravity of coal-gas is essential to the gas-maker, when it is desired to ascertain the weight of the gas produced from any sample of coal. It also serves in some degree as an index to illuminating power.

209.—To find the specific gravity of any gas with scientific exactness, a very accurate and sensitive balance must be employed, as well as two glass globes, of equal weight, and as nearly of equal size as possible, one being used to contain the air and the gas which are to be weighed, and the other as a counterpoise. Many precautions have to be taken, and great skill in manipulation is necessary. Regnault's method is described in Miller's "Chemical Physics," fourth edition, p. 264.

210.—Such extreme accuracy is, however, rarely needed for ordinary purposes, and in most cases it is sufficient to know the relation in gravity which coal-gas, containing water vapour (as it and air do under usual conditions), bears to air also containing such vapour.

211.—The quantity of water vapour in the air, or in any gas exposed to water, varies with the temperature, but is constant for each degree, while it is independent of the kind of gas. Thus, under the conditions stated, any volume of coal-gas will, at any given temperature, contain as much water vapour as is contained in an equal volume of air of the same temperature.

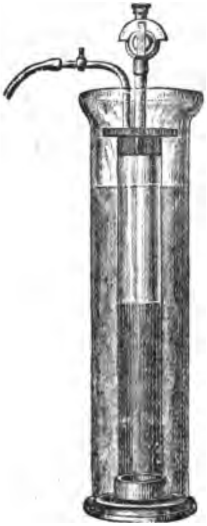

Fig. 34.

212.—The specific gravity of moist gas may be readily found by means of Schilling's effusion test, which is a modification of Bunsen's instrument. It consists (fig. 34) of a cylindrical glass vessel, within which is placed a glass tube, the latter surmounted by a metal cap, and its lower end fitted with a metal base, which serves as a foot and as a load to keep the tube immersed in water. The cap carries two cocks, one on the side and the other on a short upright pipe. The latter is a three-way cock, with a pointer and an index marked "vent," "off," and "on." The tube has two rings engraved upon it, one near to the base and the other near to the cap. The "vent" is through the plug of the cock, but when this is turned to "on," the only opening for air or gas is through a very thin disc of platinum, perforated with a minute hole, in the nozzle of the cock. The specific gravity is determined by ascertaining the time in seconds which equal volumes of air and of gas occupy in escaping from the minute orifice under equal pressures, and then dividing the square of the gas time by the square of the air time.

213.—To Use. Charge the instrument while the cock is at "vent" with water, until it reaches a little above the top line on the tube. Raise the tube nearly out of the water to charge it with air. Turn the cock to "off," and lower the tube until it rests on the bottom of the cylinder. Turn the cock to "on." The water will rise in the tube. When the lower line is reached, instantly turn the cock to "off." A stop-watch or stop-clock is most convenient for the purpose, but with care an ordinary seconds' watch will serve. In any case turn the cock to "on" the instant the seconds' hand reaches 60, and turn off, noting time instantly when the water reaches the top line.

Note.—The lower part of the hollow formed by the water, should always be the index of coincidence with the lines.

214.—Turn the cock to "vent," and connect side-cock by a piece of india-rubber pipe to gas cock; turn on the gas and let it flow through the "vent" for say half a minute, then turn the top cock to "off." Raise the tube and gas will enter. Close the side cock, and immerse the tube. Open the vent and it will rapidly escape; repeat this, and then finally charge and proceed as with air.

Suppose the times be as under:—

Gas . . 120 seconds squared = 14400

Air . . 180 „ „ = 32400

Sp. Gr. ·44

215.—Care should be taken to ensure the water in the apparatus being of the same temperature as the air in the operating room, and at least two trials should be made with the air and with the gas.

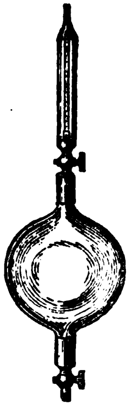

Fig. 35.

216.—A more refined method than Schilling's is that which was devised and used by the late Dr. Letheby, whose specific gravity globe is represented in fig. 35. It has two necks, each furnished with a small and light stop-cock, the upper one having screwed upon it a glass tube, surmounted by a small gas-burner, and containing a sensitive thermometer. The weight of the globe with the cocks, but without the thermometer tube, in an exhausted state and when filled with air* at 60° F. of temperature, and under 30 ins.

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* Which should be in a moist state to suit the Author's method of calculations.

barometric pressure are engraved upon the globe, or ascertained and recorded. The globe is charged with gas by being screwed upon the nose-piece of a gas-pillar, and the gas allowed to flow through and escape from the jet until all air is expelled; the lower cock is then closed, and (in order to avoid any greater pressure within the globe than that of the atmosphere) the upper cock is closed an instant later. The temperature indicated by the thermometer in the tube is at once noted, the tube removed, and the globe placed in the pan of a sensitive balance, a counterpoise weight equal to the weight of the globe in a vacuous condition being placed in the other pan of the balance, together with as many grains and parts of a grain as are needful to bring the balance into equipoise.

217.—It is absolutely essential that the outside of the globe be dry, which cannot be the case when the weighing is effected in a moist atmosphere of higher temperature than the globe, owing to the inevitable condensation of some water vapour. Hence, the balance should be enclosed in a glazed case, in which should be placed a glass vessel containing two or three ounces of dry chloride of calcium, which absorbs moisture, and the globe should be allowed to rest in the balance pan, with the case closed, for some minutes before the final weighing is made.

218.—Suppose the weight of the globe when filled with gas be 15 grains in excess of the counterpoise which equals the weight of the globe when exhausted, and also that the weight of air indicated to be contained by the globe at 60° F. and 30 in. barometer be 31 grains. Further, that the observed temperature of the gas be 56° F. and the barometric pressure 30·3 ins. (14 and 15.)

RULE.—Multiply the ascertained weight of the gas by 1000 and divide by the number (Table C, Appendix) for temperature and pressure. Finally, divide the quotient first obtained by the weight of air which the globe contains at 60° and 30 ins.

Ex.:—Weight of gas . . . . . 15 grs.
Multiply by 1000

Number for 56° and 30·3 ins. . 1020)15000(14·7058
Weight, corrected to standard temperature and pressure, 14·7058 grs.

Which corrected weight divided by the weight of air, *31 grains*, indicates the relative weight, or specific gravity, of *moist* gas to *moist* air to be as ·4743 to 1·0 or 474·3 to 1000.

220.—The true specific gravity of a gas is, however, the relative weight of any volume in a *dry* state to the weight of an equal volume of *dry* atmospheric air. This is, in a scientific way, frequently determined by weighing a globe charged with dry air, and afterwards when charged with dry gas—the water vapour in the air and gas being removed on their way to the globe, by slow delivery through a long tube containing dry chloride of calcium. Corrections can, however, be made by calculations, which, as usually set forth, are somewhat troublesome, involving as they do considerations of aqueous tension, the volume and the weight of vapour, and the subtraction of the latter two from the volume and weight of the contained gas. The Author has, therefore, essayed to confine the calculations entirely to weight, and thereby simplify the matter. As with the usual method, the volume of gas or air operated upon must, however, be known, and this, as will be seen presently, may be easily ascertained; if the weight of air contained at 60° and 30 ins. in the globe employed has been once correctly determined.

221.—DATA.—*At Standard temperature and pressure:—*

(a). One cubic *foot* of *moist* air weighs 532·4 grains,* while one cubic foot of *dry* air weighs 535·9 grains.*

(b). One cubic *inch,* therefore, of *moist* air weighs ·3081012 grain, and of dry air ·3101214 grain, and, as quite near enough, 100 cubic ins. of moist air weigh 30·81 grains.

(c). One cubic foot of moist air or gas contains 5·8 grains of water vapour, or ·33565 of a grain (say ·336 of a grain) in 100 cubic inches.

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* Simmons' Standard Tables.

The weight of air, therefore, contained in 100 inches of such a mixture would be 30·81—·336, or 30·474 grains.

222.—The weight of air contained in the globe is, as already said, determined at 60° and 30 ins. bar., with the air saturated with water vapour. Suppose the globe has been found to contain 30·964 grains, and is so marked:

> RULE TO FIND CAPACITY. Divide the marked weight of air contained in the globe by 30·81.

Ex.: $\frac{30{\cdot}964}{30{\cdot}81}$ = volume, or 100·5 cubic inches.

223.—Suppose, as before, the weight of gas contained were 15 grains (218):

> RULE TO FIND THE WEIGHT OF 100 CUB. INS. Multiply the ascertained weight by 100, and divide by the capacity of the globe.

Ex.: $\frac{15\times100}{100{\cdot}5} = \frac{1500}{100{\cdot}5} = 14{\cdot}9254$ grains,

which is the weight of 100 cubic inches of moist gas at the observed temperature and pressure.

To find the Specific Gravity of Dry Gas.

224.—Multiply the weight as above corrected by 1000, and divide by the number due to temperature and pressure (Table C, Appendix).

Subtract ·336 of a grain from the quotient, and divide the remainder by 30·474, (*c.*) 221.

Ex.: Weight corrected for bulk . 14·9254
Multiplied by 1000 = 14925·4
Divided by No. for 56° and 30·3in. 1020 = 14·6323
Subtract . . . . ·336
Divided by . . . . 30·474) 14·2963
Sp. Gr. Dry Gas = ... ·469

To Correct the Bulk and find the Weight of Gas.

225.—Bulk. Multiply the quantity of gas by the tabular number (C, Appendix) due to temperature and pressure, strike off the three right-hand figures, and the remainder is the true bulk. If the gas be subjected to pressure in excess of that of the atmosphere at the time of measuring, add one inch to the barometer's height for every thirteen inches of water pressure.—Weight. Multiply the quantity in cubic feet by the specific gravity, and strike off the three right-hand figures, then multiply the remainder by ·07605 or ·076.

Appendix.

RULES AND TABLES

TO FACILITATE THE CALCULATIONS NECESSARY IN THE DETERMINATION OF THE

ILLUMINATING VALUE

AND

DEGREE OF PURITY OF COAL GAS.

PHOTOMETRY.

Rule 1.—If the rate of the gas consumption has *fallen below* or *risen above* 5 cubic feet per hour.

Multiply the average of the photometer readings by the number under the actual consumption in Table A.

Rule 2.—Multiply the sum obtained by Rule 1 by the consumption of the two candles, as ascertained from Table B.

Rule 3.—Divide the last-obtained sum by 20, or point off to the left an additional decimal place, and divide by 2.

Rule 4.—Multiply the quotient obtained by Rule 3 by 1000 (*i.e.*, set back the decimal point 3 places to the right), and divide by the tabular number corresponding to pressure and temperature* in Table C.

---

* The temperature to be observed is that of the gas issuing from the meter, and not that of the air.

AMMONIA AND SULPHUR.

RULE 1.—Take the readings of the barometer on the day the testings commence, and also on the day on which they close. The mean of the two is the pressure and temperature (Note * on previous page) under which the tabular number is to be sought in Table C.

RULE 2.—Multiply the number of grains of barium sulphate obtained by operating upon *half* the liquid resulting from the burning of 10 c. ft. of gas by 11 and divide by 4, again multiply the quotient by 1000 and divide by the tabular number due to pressure and temperature, remove the decimal point 3 additional places to the left, and the result will be the number of grains of sulphur in 100 c. ft. of the gas.

RULE 3.—The correction may be made with sufficient accuracy in the following manner: after the multiplication by 11 and the division by 4 of the sulphate obtained, add to or subtract from the weight found as under:—

Tab. No. between	955-965	966-975	976-985	986-995
	1-400th	1-300th	1-200th	1-100th

Tab. No. between 996-1005 no correction.

Tab. No. between	1006-1015	1016-1025	1026-1035
	1-100th	1-200th	1-300th

No correction is made in respect to ammonia, its quantity being so small.

The Table C is from 40° upwards a copy of that issued by the Referees, the numbers for lower temperatures having been calculated by the Author. The numbers will be found useful in reducing the volume measured by a meter or gasholder to standard bulk (225).

Note.—The numbers in the Table C have been recalculated from the formula $n = \frac{17{\cdot}64\,(h-a)}{460 \times t}$, where h is the height of the barometer in inches, t the temperature on the Fahrenheit scale, and a the tension of aqueoús vapour at t°. If v is any volume at t° and h inches pressure, and V the corresponding volume at 60° and 30 inches pressure, $V = v\,n$.

The numbers in Table C show the relation of volume to 1000, but when three figures are marked off as decimals, the numbers show the relation of Vol. to Unity.

Ex. . . . 984 to 1000,
or
·984 to 1.

TABLE A.

Gas—C. ft. per hour	4·7	4·75	4·8	4·85	4·9	4·95	5·0
Multiplier . .	1·06	1·05	1·04	1·03	1·02	1·01	0·0

Gas—C. ft. per hour	5·05	5·1	5·15	5·2.	5·25	5·3	5·35
Multiplier . .	·990	·980	·971	·961	·952	·943	·934

TABLE B.

2 Candles. — Consumpt of 40 grains of Sperm in Min.	Secs.	2 Candles. — Consumpt in 10 Minutes. — Grains.	Consumpt for one Candle per hour. — Grains.	2 Candles. — Consumpt of 40 grains of Sperm in Min.	Secs.	2 Candles. — Consumpt in 10 Minutes. — Grains.	Consumpt for one Candle per hour. — Grains.
10	31	38·03	114·1	9	58	40·13	120·4
10	30	38·1	114·29	9	57	40·2	120·6
10	29	38·16	114·58	9	56	40·26	120·8
10	28	38·21	114·65	9	55	40·33	121·
10	27	38·31	114·8	9	54	40·4	121·21
10	26	38·33	115·	9	53	40·47	121·41
10	25	38·40	115·2	9	52	40·54	121·62
10	24	38·46	115·38	9	51	40·6	121·82
10	23	38·52	115·56	9	50	40·67	122·01
10	22	38·58	115·75	9	49	40·74	122·22
10	21	38·64	115·92	9	48	40·81	122·44
10	20	38·71	116·12	9	47	40·88	122·65
10	19	38·77	116·31	9	46	40·95	122·86
10	18	38·83	116·5	9	45	41·02	123·07
10	17	38·9	116·69	9	44	41·09	123·27
10	16	38·96	116·88	9	43	41·16	123·49
10	15	39·02	117·07	9	42	41·23	123·71
10	14	39·08	117·26	9	41	41·3	123·92
10	13	39·15	117·45	9	40	41·38	124·13
10	12	39·21	117·64	9	39	41·45	124·35
10	11	39·28	117·84	9	38	41·52	124·56
10	10	39·34	118·03	9	37	41·59	124·78
10	9	39·41	118·22	9	36	41·66	125·
10	8	39·47	118·41	9	35	41·74	125·21
10	7	39·54	118·61	9	34	41·81	125·43
10	6	39·6	118·81	9	33	41·88	125·65
10	5	39·66	119·	9	32	41·96	125·87
10	4	39·73	119·2	9	31	42·03	126·09
10	3	39·8	119·4	9	30	42·1	126·31
10	2	39·87	119·6	9	29	42·18	126·53
10	1	39·93	119·8	9	28	42·25	126·75
10	0	40·0	120·	9	27	42·32	126·97
9	59	40·06	120·2	9	26	42·4	127·2

TABLE C.

BAR.	THER. 32°	34°	36°	38°	40°	42°	44°	46°	48°	50°	52°	54°	56°	58°
28·0	998	993	988	984	979	974	970	965	960	956	951	946	942	937
28·1	1002	997	993	988	983	978	973	969	964	959	955	951	945	941
28·2	1006	1001	996	991	986	981	977	972	967	963	958	953	949	944
28·3	1009	1004	1000	995	990	985	980	976	971	966	961	957	952	947
28·4	1012	1007	1002	998	993	988	984	979	974	970	965	960	955	951
28·5	1016	1011	1006	1001	997	992	987	983	978	973	968	964	959	954
28·6	1020	1115	1010	1005	1001	995	991	986	981	977	972	967	962	958
28·7	1023	1018	1013	1009	1004	999	994	990	985	980	975	970	966	961
28·8	1027	1022	1017	1012	1007	1003	998	993	988	984	979	974	969	964
28·9	1031	1026	1021	1016	1011	1006	1001	997	992	987	982	977	973	968
29·0	1034	1029	1024	1019	1014	1010	1005	1000	995	990	986	981	976	971
29·1	1038	1033	1028	1023	1018	1013	1008	1004	999	994	989	984	979	975
29·2	1041	1036	1031	1026	1021	1017	1012	1007	1002	997	992	988	982	978
29·3	1045	1040	1035	1030	1025	1020	1015	1011	1006	1001	996	991	986	981
29·4	1048	1043	1038	1033	1028	1024	1019	1014	1009	1004	999	995	990	985

TABLE C—*continued.*

BAR.	THER. 32°	34°	36°	38°	40°	42°	44°	46°	48°	50°	52°	54°	56°	58°
29·5	1052	1046	1041	1036	1032	1027	1022	1018	1013	1008	1003	998	993	988
29·6	1055	1050	1045	1040	1036	1031	1026	1021	1016	1011	1006	1001	996	992
29·7	1059	1054	1049	1044	1039	1034	1029	1025	1019	1015	1010	1005	1000	995
29·8	1063	1058	1053	1048	1043	1038	1033	1028	1023	1018	1013	1008	1003	998
29·9	1066	1061	1056	1051	1046	1041	1036	1031	1026	1022	1017	1012	1007	1002
30·0	1070	1065	1060	1055	1050	1045	1040	1035	1030	1025	1020	1015	1010	1005
30·1	1073	1068	1063	1058	1053	1048	1043	1038	1033	1029	1024	1019	1014	1009
30·2	1076	1071	1066	1062	1057	1052	1047	1042	1037	1032	1027	1022	1017	1012
30·3	1080	1075	1070	1065	1060	1055	1050	1045	1040	1036	1030	1025	1020	1015
30·4	1084	1079	1074	1069	1064	1059	1054	1049	1044	1039	1034	1029	1024	1019
30·5	1087	1082	1077	1072	1067	1062	1057	1052	1047	1042	1037	1032	1027	1022
30·6	1090	1085	1080	1075	1071	1066	1061	1056	1051	1046	1041	1036	1031	1026
30·7	1094	1089	1084	1079	1074	1069	1064	1059	1054	1049	1044	1039	1034	1029
30·8	1098	1093	1088	1083	1078	1073	1068	1063	1058	1053	1048	1043	1037	1032
30·9	1101	1096	1091	1086	1081	1076	1071	1066	1061	1056	1051	1046	1041	1036
31·0	1105	1100	1095	1090	1085	1080	1075	1070	1065	1060	1055	1049	1044	1039

TABLE C—*continued.*

BAR.	THER. 60°	62°	64°	66°	68°	70°	72°	74°	76°	78°	80°	82°	84°
28·0	932	927	922	917	912	907	902	897	892	887	881	875	870
28·1	936	930	926	921	916	911	905	900	895	890	884	879	873
28·2	939	934	929	924	919	914	909	904	898	893	887	882	876
28·3	942	937	932	928	922	917	912	907	902	896	891	885	880
28·4	946	941	936	931	926	921	915	910	905	900	894	888	883
28·5	949	944	939	934	929	924	919	914	908	903	897	892	886
28·6	953	947	943	938	932	927	922	917	912	906	901	895	889
28·7	956	951	946	941	936	931	925	920	915	909	904	898	893
28·8	959	954	949	944	939	934	929	924	918	913	907	901	896
28·9	963	958	953	948	942	937	932	927	921	916	910	905	899
29·0	966	961	956	951	946	941	935	930	925	919	914	908	903
29·1	969	964	959	954	949	944	939	933	928	923	917	911	906
29·2	973	968	963	958	952	947	942	937	931	926	920	914	909
29·3	976	971	966	961	956	950	945	940	935	929	923	918	912
29·4	980	975	969	964	959	954	949	943	938	932	927	921	915

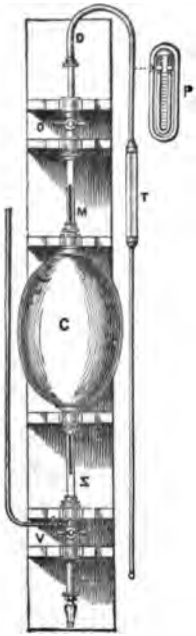
TABLE C—*continued.*

BAR.	THER. 60°	62°	64°	66°	68°	70°	72°	74°	76°	78°	80°	82°	84°
29·5	983	978	973	968	962	957	952	947	941	936	930	924	919
29·6	986	981	976	971	966	960	955	950	944	939	933	927	922
29·7	990	985	980	974	969	964	959	953	948	942	937	931	925
29·8	993	988	983	978	972	967	962	957	951	946	940	934	928
29·9	997	991	986	981	976	970	265	960	954	949	943	937	932
30·0	1000	995	990	985	979	974	968	963	958	952	946	941	935
30·1	1003	998	993	988	983	977	972	966	961	955	950	944	938
30·2	1007	1002	996	991	886	980	975	970	964	959	953	947	941
30·3	1010	1005	1000	995	989	984	978	973	968	962	956	950	945
30·4	1014	1008	1003	998	993	987	982	976	971	965	959	954	948
30·5	1017	1012	1006	1001	996	990	985	980	974	969	963	957	951
30·6	1020	1015	1010	1005	999	994	988	983	977	972	966	960	954
30·7	1024	1018	1013	1008	1003	997	992	986	981	975	969	963	957
30·8	1027	1022	1017	1011	1006	1000	995	990	984	978	972	967	961
30·9	1031	1025	1020	1015	1009	1004	998	993	987	982	976	970	964
31·0	1034	1029	1023	1018	1013	1007	1002	996	991	985	979	973	967

E.—Proving of Testing Meters in London.

The Referees in the instructions they issue direct that the meters used for measuring the gas consumed in making the various testings shall, at periods of not less than seven days, be proved by the Gas Examiner by means of the Referees' cubic-foot measure,—a description of which apparatus, with directions how to use it, is given as follows:—Should a meter show any variation, water must be added or withdrawn until the meter is correct. Every testing-place shall have the above-mentioned apparatus, so that the Gas Examiner may employ it whenever he thinks necessary.

No meter other than a wet one shall be used in testing the gas under these instructions.



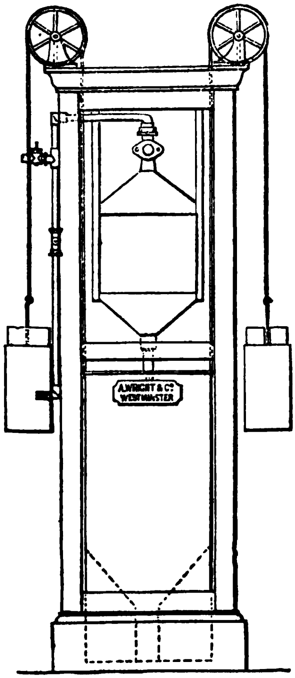
The Gas Referees' Cubic-foot Measure.

This is a vessel, egg shaped, as in the figure C, made of hardened tin about one quarter of an inch thick, fitted at each end with a narrow glass-tube M Z. It is fixed to a strong plank, and stands in a vertical position. At O is a three-way cock with a ⊤ mark on the plug, and at the side of the cock there is a small hole or vent. When the ⊤ is in its ordinary position, communication is cut off from the air-pipe D, but is open through the vent to the external air. In this position ⊣ of the mark, the measure is open to the pipe D, and is shut off from the external air. In the side or water pipe above V, there is a small cock (not shown in the print), which when opened serves to admit water into the measure, while at V is a larger cock by which to run the water off. The pipe D is of tin, in connection with the inlets of the meters in the testing-room or rooms. It carries a thermometer within a glass tube at T, and has also attached to it a pressure-gauge P. The terminal points of capacity are defined by narrow strips of paper pasted on, or by marks cut upon the glass-tubes MZ. The instrument should be in communication with a tank of water, fed by a self-acting supply through the water pipe, and the lower level of the tank should be level with the top of the slip of paper or mark on M, indicating the "full" line of the measure.

The verification of the meters used with the photometers and the sulphur and ammonia tests is conducted as follows:—

Turn the three-way cock O, so as to leave the vent open to the air, and close the cock V, then open the cock on the water-pipe, and allow sufficient water to flow in to fill the glass tube S to the water line. Then turn O until the mark upon it is in this position ⊣. Next open the cock of the meter to be tested, taking care that all other connections are closed. Note the position of the pointers of the meters, and open the outlet of the meter to the air. Then gently open the cock on the water pipe, and allow the water to flow into the measure, just fast enough to cause the gauge P to indicate from half to three-quarter inch of pressure. The meter should make 12 revolutions, or indicate one cubic foot by the time the measure is full up to the mark on the glass tube M. Should the meter make more than the prescribed number of revolutions, then some water must be removed from it; if the contrary is the case, then water must be added to its contents. The testing is to be repeated until the meter is found to register correctly. The circle of the photometer meter which indicates each revolution of the measuring drum, or one-twelfth of a cubic foot, is divided into 50 divisions, each of which therefore represents 1-500th of a cubic foot. Consequently six of these divisions represents one per cent. Some sulphur-meters have a similar circle, but others have a circle indicating one cubic foot, which circle is divided into 100 parts, each division of which consequently represents one per cent. The difference of about an ounce in the quantity of water in the meters, when they are charged nearly to the water level, will make them register one per cent. either fast or slow. If the temperature indicated at T be higher or lower than the temperature at the outlet of the meter, the volume indicated by the meter must be corrected, in order to find the volume which the meter ought to register at the time of testing. Divide the number (Table C) corresponding with the temperature and barometer pressure of the cubic foot measure by the number corresponding with the barometer pressure and the temperature of the meter.

This system of testing the meters constitutes a refinement, which it is needless to adopt in the majority of cases. If a meter be provided with a water-line gauge, stand perfectly level, and be kept clean internally, the water level can always be adjusted readily, and with the certainty, according to the Author's experience, that any error will not exceed 1-5th of a per cent., so that the possible error with 16 candle gas would be 0·032 of a candle, while with gas containing 20 grains of sulphur, the error might be ·04 of a grain. It is very doubtful if with such refined meter testing, more accurate results are obtained. If, however, a meter is allowed to get foul, and its working resistance or friction increases very much, errors may arise. The working friction of a testing meter should therefore be frequently ascertained (see par. 32), and should not exceed one-tenth of an inch.



With the Referees' measure, a cubic foot of water is needed for every cubic foot of air measured, and extreme care and watchfulness must be exercised. The Author's method is, he thinks, much more facile, The bottle is mounted within a strong frame, and below it is a water tank, which, when charged, is nearly counterpoised by weights, so that the application of certain other loose weights causes the tank to rise or fall, while their removal causes the tank to descend. In rising, the air in the bottle is expelled through the air-pipe, then through a well made wet-governor, and thence through the meter to be measured. No error does or can arise from the intervention of the governor. At the outset the governor is weighted to the needful extent, say to give five or six-tenths pressure, and the cubic foot measure, governor, and meter connected together by pipes, and their aëriform contents brought into equilibrium with the atmosphere. The necessary loose counterpoise weights being applied, the tank rises, water enters the lower part of the bottle, driving the contained air forward, the governor comes into action, and when all air has been expelled from the bottle, the governor delivers the air which it has received to the meter, and again a state of equilibrium is attained. This system has been severely tested by the Author. It is easy to work, there is no waste of water, and the latter may be maintained at, or readily brought to, the same temperature as the testing room.

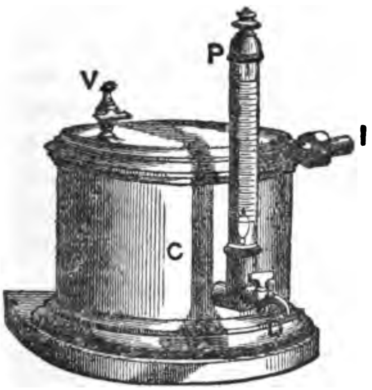
F.—Times and Mode of Testing for Pressure in London.

" Six observations shall be made daily of the pressure " at which gas is supplied, and of these observations, " three shall be made during the interval from midnight " to sunset, and three during the interval from sunset to " midnight.

" The apparatus prescribed for the purpose is that known " as the Referees' Pressure Gauge, a description of which " is given in Appendix, to the instructions issued by the Referees.

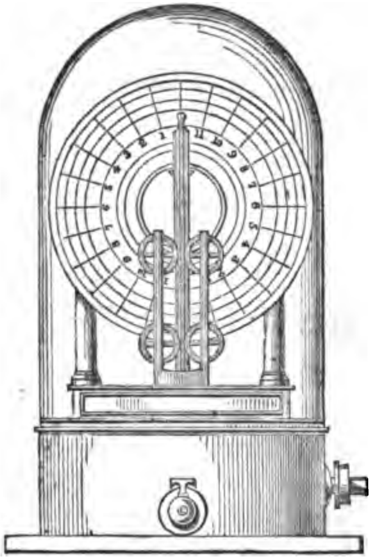
" The line round the float must first be brought to " coincide with the zero line of the graduated glass tube, " the stopcock for admitting gas being closed, and that at " the top of the apparatus being open. If necessary, water

" is to be added or drawn off until a perfect coincidence " has been obtained. Then, the outlet having been closed, " gas should be admitted gradually. Readings are to be " made to one hundredth of an inch, and represent directly " the pressure of the gas."



The form of the Referees' Pressure Gauge is shown in the cut. C represents the body of the instrument, I the inlet for gas, D the outlet for water, P the graduated tube with float inside, V the outlet for gas and inlet for water.

When it is desired to ascertain and record the pressures during the successive hours of the day and night, a registering gauge (next page) should be employed. The base or body consists of two cylinders, one centrally placed within the other, and both in communication at their lower ends, the annular space at the top being closed. A float plays within the centre cylinder, and supports a brass rod surmounted by a pencil, which impinges upon a paper scale attached to a metal plate, which is rotated by a strong clock. The cylinders are charged with water until the pencil rises to the zero of the scale. On the admission of gas into the outer cylinder, the water will be forced up



in the inner cylinder to a degree proportionate to the pressure, and the pencil will mark the pressure on the scale. As the instrument necessarily works with a little friction, the pressures will have been with a rising pencil about one-tenth of an inch higher than indicated, and with a *falling* pencil about one-tenth lower.

It is indispensable when the pressure in the main is sought that there should be no draught on, or escape of gas from, the connecting pipe to any pressure gauge. When possible, therefore, an independent "pressure service" should be laid on to the testing-room.

G.—Proposed Standards of Light.

Many standards of light, whereby to estimate the value of coal-gas, have been proposed during the past 25 years, but it may be fairly asserted that only two of the number possess such characteristics as render them worth serious attention for official testings. These two are the Pentane Gas of Vernon

Harcourt, Esq., and the Improved Lamp, invented by W. Keates, Esq., for burning sperm oil.

HARCOURT'S STANDARD FLAME. Mr. Harcourt lays down a proposition of the soundest character, viz., "that since the value of an illuminant depends "solely upon such parts of the total force radiating "from a flame as affect the human eye, no test of "illuminating power can be satisfactory which does "not depend upon vision; at least, until it has been "proved that some other effect of radiation is for all "flames in direct proportion to the effect on the optic "nerve. Such a relation seems improbable, and cannot be established until some exact mode of measuring the visual effect has first been found."*

Mr. Harcourt further says, "The combustible "must be of known and definite composition. The "condition of burning must be of a simple and "definable character. The nature of the combustible "and the conditions of burning must be such that "atmospheric changes may produce a minimum of "effect upon the light. The operator should be able "to verify for himself the composition of the combustible he employs."

The standard combustible which Mr. Harcourt proposes consists of "a mixture of air with that "portion of American petroleum which, after repeated "rectifications, distils at a temperature not exceeding

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* "On a new kind of Light for Photometry."—August, 1877.

" 50° C. (122° F.) The liquid thus obtained consists
" almost entirely of pentane, the fifth member of the
" series of paraffins. Its vapour density was found
" to be 37, the theoretical density of gaseous pentane
" as compared with hydrogen being 36. The liquid
" used in the experiments made has a specific gravity
" which has only varied in different samples, prepared
" from petroleum obtained from different sources, be-
" tween ·628 and ·631."

The standard gas is made by pouring a measured quantity of pentane into a small gasholder, previously charged with a measured quantity of air. For every cubic foot of air the required volume of pentane is three cubic inches. The volume of air is measured either by a meter or by a scale attached to the gasholder, and is drawn in by adding weights to the counterpoise. The liquid is measured in a small flask, whence it is poured through a tap in the upper plate of the gasholder. A convenient quantity of the standard gas to prepare at one time is four cubic feet, which is sufficient for from forty to fifty testings and requires a gasholder of only five or six cubic feet capacity.

If the liquid pentane comes into contact with the plug of the tap, it acts upon the lubricating grease, and may induce leakage. To prevent this, a piece of caoutchouc holding a glass tube which can slide up and down, is placed in the mouth of the tap, and the measuring flask is furnished with a stopper, also holding a glass tube. The two are connected by means of a piece of red-rubber piping. The tap is then opened, and the glass tube pushed downwards through the plug of the tap into the gasholder. The flask is then inverted, and the pentane is poured in. When the flask is emptied, the sliding tube is gently worked upwards until its end clears the plug of the tap, which is known by observing a mark on the tube; the tap is then closed, and the flask disconnected. Complete volatilisation and diffusion will take place within about five hours, when, if the barometer be at 30 inches and the temperature be 60° Fahr., and if the gasholder be perfectly balanced, so as to exercise no pressure on the contained gas, the volume of the latter should be 4·05 cubic feet, if nine cubic inches of pentane have been added to three cubic feet of air. The relation between the density of pentane in the liquid and the gaseous condition is such, that one cubic inch of the liquid yields rather more than 200 cubic inches of vapour; and thus nine cubic inches yield about 1 and 1-20th cubic foot (= 1814 cubic inches).

The liquid pentane may be always measured correctly by warming or cooling to 60° Fahr., or by using a flask, graduated for volume at various temperatures, but the air volume must be found by calculation (14—15).

Rule.—Multiply the volume intended to be taken (say 3 cubic feet) by 1000, and then divide by the number (Table C) due to the actual pressure and temperature.

Ex. :—Bar., 30·4. Temp., 48°. Number, 1044.

$$\frac{3 \times 1000}{1044} = 2{\cdot}873$$

the number of cubic feet of air required at 30·4 ins. and 48° Fahr.

When the pentane gas has been made, its volume is read on the scale of the gasholder, and corrected as above to the volume it would occupy at 60° Fahr., and under a barometric pressure of 30 inches. Deducting the volume of gas previously in the holder, and the three cubic feet of air introduced, the remainder is the volume of pentane vapour which has been formed. If it is within two or three per cent. of 1·05 cubic foot, the correctness of the operation of preparing the gas is established.

The burner consists of a brass tube one inch in diameter and four inches long, furnished at the top with a soundly-fitting brass plug half-an-inch in thickness, having a central hole exactly a quarter of an inch in diameter. With pentane gas issuing at the rate of half a cubic foot per hour, a steady flame is produced 2½ inches long, and equal to the average light given by a standard sperm candle (8). The height of the flame is indicated by a platinum wire carried by an upright rod attached to the side of the burner. The gas is measured by a little wet meter of only 1-60th of a cubic foot measuring capacity, which Mr. Harcourt adopted at the Author's suggestion.

There is but little difficulty in preparing or in using the gas; all that is needed is intelligence and carefulness, as the Author can testify, after some experience, which, however, has not been extensive enough to justify any absolute expression of opinion. Certain it seems to be, that this gas does not deteriorate in quality, but is only subject in that respect, as all gases are, to increase and diminution in density under changes of pressure and temperature, for which corrections are made by calculation in the same way as practised with coal-gas.

CARCEL LAMP.—It was proposed some years since to adopt in this country the same standard of light as that employed in France, namely, that produced by the consumption of 648 grains (42 grammes) of colza oil per hour, burned from a Carcel lamp of certain absolute dimensions and under specified conditions. The favourable opinion expressed for this lamp by some scientific men, induced the Author to obtain several standard lamps from Paris, together with the necessary wicks and oil, and to engage in a series of several hundreds of very carefully-conducted experiments, the results of which, in spite of his predilections, forced him to the conclusion that the Carcel lamp, while demanding much more trouble and attention than sperm candles, was, as a standard, but little, if any, more to be relied upon for constancy of light.

KEATES' LAMP.—In the year 1869, Mr. Keates published particulars relative to his Moderator Lamp, which he suggested as a standard light for illuminating power in place of sperm candles. With this lamp Mr. Keates used sperm oil, instead of colza or any other vegetable oil, on account of its greater fluidity and its low specific gravity, which renders adulteration by inferior oils almost impossible. The consumption rate with the original lamp was 750 to 760 grains of oil per hour, and the light yielded equal to about 10 sperm candles' power; but within a recent period modifications and improvements have been made in the burner, and other details, by Mr. W. Sugg, which have raised the hourly consumption of the oil to about 980 grains, with a flame length of two inches and the light yielded to about 16 candles. The Author has had no opportunity of working with this lamp, but is assured by competent authorities that the light which it affords is very constant after the first quarter of an hour or so of burning. Mr. Keates is still experimenting with it, and will, no doubt, when possible, publish full particulars of the proper mode of using and the results obtained. In use, the lamp is suspended from the beam of a steelyard balance affixed to the end of the photometer, so that adjustments of the flame, etc., are made, and the rate of consumption of the oil determined, while the lamp-flame is burning, and while in position for use.

Fiddes' Light.—About thirteen or fourteen years ago, Mr. Fiddes, of Bristol, stated that the amount of light passing through a circular hole about a quarter of an inch in diameter, and at a certain height, in an opaque chimney surrounding an Argand flame, was constant, or nearly so, notwithstanding that the gases supplied to the burner might differ very much in illuminating power, and he proposed such a burner and chimney in substitution for candles. The Author made a considerable number of trials with Mr. Fiddes' burner, but failed to secure such an approximation to constancy in light as had been predicated. The causes of his complete failures he now believes to have been, first, neglect in making a sufficient number of experiments to determine the proper shape and position for the hole, through which the light was emitted, and, secondly, in the use of an opaque chimney instead of a slotted screen.

Methvin's Light.—Experimenting in the same direction as Mr. Fiddes had done, but apparently without any knowledge of what had been attempted, Mr. John Methvin, of the London Gas Works, carried out a series of exhaustive experiments, which led him to the conclusion that the quantity of light which would pass through a vertical slot ¼-inch wide and 1 in. long, in an opaque screen, at a definite height from the base of an Argand flame three inches long, or very nearly so, was equal for all qualities of gas—and certainly so for qualities between 15 and 35 candles' power—the burner employed being a London Argand No. 1, and the screen being placed very near to, and at a fixed distance from, the burner. Mr. Methvin explained his system fully in a paper read before the British Association of Gas Managers, June, 1878,. The Author ventured to dispute the reliability of the proposed standard in two letters to the "Journal of Gas Lighting," and still adheres to his objections to the proposed standard as an *official* one, but is bound to admit that, as a supplement to the usual standard (sperm candles), it is likely to be of great value to the gasmaker, inasmuch as a very close approximation to the illuminating power of the gas being made or delivered, may, by Mr. Methvin's system, be at any moment promptly obtained. Some experiments made by the Author, under by no means the best conditions, with rich cannel gas and coal gas of about 16 candles' power, gave an extreme difference of 2½ per cent., and a mean difference of about 1½ per cent.

⁂

16·20 15·97 16·73

Illuminating Power at .	……	16·20
” ” .	……	15·97
” ” .	……	16·73

3) 48·90

Divide the average Illuminating Power by the tabular number corresponding to Temperature and Pressure: the quotient will be the corrected Illuminating Power for the day.

Average Illuminating Power, uncorrected } = 16·30 Candles.

```
Tabular
number  ·995) 16·30 (16·38 = Corrected Average
               995             Illuminating Power
               ———                for the day.
               6350
               5970
               ————
                3800
                2985
                ————
                 8150
                 7960
```

………………………………………

Gas Examiner.

Appendix.

RULES AND TABLES

TO FACILITATE THE CALCULATIONS NECESSARY IN THE DETERMINATION OF THE

ILLUMINATING VALUE

AND

DEGREE OF PURITY OF GAS COALS.

PHOTOMETRY.

Rule 1.—If the rate of the gas consumption has *fallen below* or *risen above* 5 cubic feet per hour.

Multiply the average of the photometer readings by the number under the actual consumption in Table A.

Rule 2.—Multiply the sum obtained by Rule 1 by the consumption of the two candles, as ascertained from Table B.

Rule 3.—Divide the last-obtained sum by 20, or point off to the left an additional decimal place, and divide by 2.

Rule 4.—Multiply the quotient obtained by Rule 3 by 1000 (*i.e.*, set back the decimal point 3 places to the right), and divide by the tabular number corresponding to pressure and temperature* in Table C.

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* The temperature to be observed is that of the gas issuing from the meter, and not that of the air.

AMMONIA AND SULPHUR.

Rule 1.—Take the readings of the barometer on the day the testings commence, and also on the day on which they close. The mean of the two is the pressure and temperature (Note * on previous page) under which the tabular number is to be sought in Table C.

Rule 2.—Multiply the number of grains of barium sulphate obtained by operating upon *half* the liquid resulting from the burning of 10 c. ft. of gas by 11 and divide by 4, again multiply the quotient by 1000 and divide by the tabular number due to pressure and temperature, remove the decimal point 3 additional places to the left, and the result will be the number of grains of sulphur in 100 c. ft. of the gas.

Rule 3.—The correction may be made with sufficient accuracy in the following manner: after the multiplication by 11 and the division by 4 of the sulphate obtained, add to or subtract from the weight found as under:—

Tab. No. between	955-965	966-975	976-985	986-995
	1-400th	1-300th	1-200th	1-100th

Tab. No. between 996-1005 no correction.

Tab. No. between	1006-1015	1016-1025	1026-1035
	1-100th	1-200th	1-300th

No correction is made in respect to ammonia, its quantity being so small.

The Table C is from 40° upwards a copy of that issued by the Referees, the numbers for lower temperatures having been calculated by the Author. The numbers will be found useful in reducing the volume measured by a meter or gasholder to standard bulk (225).

Note.—The numbers in the Table C have been recalculated from the formula $n = \frac{17{\cdot}64\,(h-a)}{460 \times t}$, where h is the height of the barometer in inches, t the temperature on the Fahrenheit scale, and a the tension of aqueous vapour at t°. If v is any volume at t° and h inches pressure, and V the corresponding volume at 60° and 30 inches pressure, $V = v\,n$.

The numbers in Table C show the relation of volume to 1000, but when three figures are marked off as decimals, the numbers show the relation of Vol. to Unity.

Ex. . . 984 to 1000,
or
·984 to 1.

TABLE A.

Gas—C. ft. per hour	4·7	4·75	4·8	4·85	4·9	4·95	5·0
Multiplier . .	1·06	1·05	1·04	1·03	1·02	1·01	0·0
Gas—C. ft. per hour	5·05	5·1	5·15	5·2	5·25	5·3	5·35
Multiplier . .	·990	·980	·971	·961	·952	·943	·934

TABLE B.

2 Candles. — Consumpt of 40 grains of Sperm in		2 Candles. — Consumpt in 10 Minutes. —	Consumpt for one Candle per hour. —	2 Candles. — Consumpt of 40 grains of Sperm in		2 Candles. — Consumpt in 10 Minutes. —	Consumpt for one Candle per hour. —
Min.	Secs.	Grains.	Grains.	Min.	Secs.	Grains.	Grains.
10	31	38·03	114·1	9	58	40·13	120·4
10	30	38·1	114·29	9	57	40·2	120·6
10	29	38·16	114·58	9	56	40·26	120·8
10	28	38·21	114·65	9	55	40·33	121·
10	27	38·31	114·8	9	54	40·4	121·21
10	26	38·33	115·	9	53	40·47	121·41
10	25	38·40	115·2	9	52	40·54	121·62
10	24	38·46	115·38	9	51	40·6	121·82
10	23	38·52	115·56	9	50	40·67	122·01
10	22	38·58	115·75	9	49	40·74	122·22
10	21	38·64	115·92	9	48	40·81	122·44
10	20	38·71	116·12	9	47	40·88	122·65
10	19	38·77	116·31	9	46	40·95	122·86
10	18	38·83	116·5	9	45	41·02	123·07
10	17	38·9	116·69	9	44	41·09	123·27
10	16	38·96	116·88	9	43	41·16	123·49
10	15	39·02	117·07	9	42	41·23	123·71
10	14	39·08	117·26	9	41	41·3	123·92
10	13	39·15	117·45	9	40	41·38	124·13
10	12	39·21	117·64	9	39	41·45	124·35
10	11	39·28	117·84	9	38	41·52	124·56
10	10	39·34	118·03	9	37	41·59	124·78
10	9	39·41	118·22	9	36	41·66	125·
10	8	39·47	118·41	9	35	41·74	125·21
10	7	39·54	118·61	9	34	41·81	125·43
10	6	39·6	118·81	9	33	41·88	125·65
10	5	39·66	119·	9	32	41·96	125·87
10	4	39·73	119·2	9	31	42·03	126·09
10	3	39·8	119·4	9	30	42·1	126·31
10	2	39·87	119·6	9	29	42·18	126·53
10	1	39·93	119·8	9	28	42·25	126·75
10	0	40·0	120·	9	27	42·32	126·97
9	59	40·06	120·2	9	26	42·4	127·2

TABLE C.

BAR.	THER. 32°	34°	36°	38°	40°	42°	44°	46°	48°	50°	52°	54°	56°	58°
28·0	998	993	988	984	979	974	970	965	960	956	951	946	942	937
28·1	1002	997	993	988	983	978	973	969	964	959	955	951	945	941
28·2	1006	1001	996	991	986	981	977	972	967	963	958	953	949	944
28·3	1009	1004	1000	995	990	985	980	976	971	966	961	957	952	947
28·4	1012	1007	1002	998	993	988	984	979	974	970	965	960	955	951
28·5	1016	1011	1006	1001	997	992	987	983	978	973	968	964	959	954
28·6	1020	1115	1010	1005	1001	995	991	986	981	977	972	967	962	958
28·7	1023	1018	1013	1009	1004	999	994	990	985	980	975	970	966	961
28·8	1027	1022	1017	1012	1007	1003	998	993	988	984	979	974	969	964
28·9	1031	1026	1021	1016	1011	1006	1001	997	992	987	982	977	973	968
29·0	1034	1029	1024	1019	1014	1010	1005	1000	995	990	986	981	976	971
29·1	1038	1033	1028	1023	1018	1013	1008	1004	999	994	989	984	979	975
29·2	1041	1036	1031	1026	1021	1017	1012	1007	1002	997	992	988	982	978
29·3	1045	1040	1035	1030	1025	1020	1015	1011	1006	1001	996	991	986	981
29·4	1048	1043	1038	1033	1028	1024	1019	1014	1009	1004	999	995	990	985

TABLE C—*continued.*

BAR.	THER. 32°	34°	36°	38°	40°	42°	44°	46°	48°	50°	52°	54°	56°	58°
29·5	1052	1046	1041	1036	1032	1027	1022	1018	1013	1008	1003	998	993	988
29·6	1055	1050	1045	1040	1036	1031	1026	1021	1016	1011	1006	1001	996	992
29·7	1059	1054	1049	1044	1039	1034	1029	1025	1019	1015	1010	1005	1000	995
29·8	1063	1058	1053	1048	1043	1038	1033	1028	1023	1018	1013	1008	1003	998
29·9	1066	1061	1056	1051	1046	1041	1036	1031	1026	1022	1017	1012	1007	1002
30·0	1070	1065	1060	1055	1050	1045	1040	1035	1030	1025	1020	1015	1010	1005
30·1	1073	1068	1063	1058	1053	1048	1043	1038	1033	1029	1024	1019	1014	1009
30·2	1076	1071	1066	1062	1057	1052	1047	1042	1037	1032	1027	1022	1017	1012
30·3	1080	1075	1070	1065	1060	1055	1050	1045	1040	1036	1030	1025	1020	1015
30·4	1084	1079	1074	1069	1064	1059	1054	1049	1044	1039	1034	1029	1024	1019
30·5	1087	1082	1077	1072	1067	1062	1057	1052	1047	1042	1037	1032	1027	1022
30·6	1090	1085	1080	1075	1071	1066	1061	1056	1051	1046	1041	1036	1031	1026
30·7	1094	1089	1084	1079	1074	1069	1064	1059	1054	1049	1044	1039	1034	1029
30·8	1098	1093	1088	1083	1078	1073	1068	1063	1058	1053	1048	1043	1037	1032
30·9	1101	1096	1091	1086	1081	1076	1071	1066	1061	1056	1051	1046	1041	1036
31·0	1105	1100	1095	1090	1085	1080	1075	1070	1065	1060	1055	1049	1044	1039

TABLE C—*continued.*

BAR.	THER. 60°	62°	64°	66°	68°	70°	72°	74°	76°	78°	80°	82°	84°
28·0	932	927	922	917	912	907	902	897	892	887	881	875	870
28·1	936	930	926	921	916	911	905	900	895	890	884	879	873
28·2	939	934	929	924	919	914	909	904	898	893	887	882	876
28·3	942	937	932	928	922	917	912	907	902	896	891	885	880
28·4	946	941	936	931	926	921	915	910	905	900	894	888	883
28·5	949	944	939	934	929	924	919	914	908	903	897	892	886
28·6	953	947	943	938	932	927	922	917	912	906	901	895	889
28·7	956	951	946	941	936	931	925	920	915	909	904	898	893
28·8	959	954	949	944	939	934	929	924	918	913	907	901	896
28·9	963	958	953	948	942	937	932	927	921	916	910	905	899
29·0	966	961	956	951	946	941	935	930	925	919	914	908	903
29·1	969	964	959	954	949	944	939	933	928	923	917	911	906
29·2	973	968	963	958	952	947	942	937	931	926	920	914	909
29·3	976	971	966	961	956	950	945	940	935	929	923	918	912
29·4	980	975	969	964	959	954	949	943	938	932	927	921	915

TABLE C—*continued.*

BAR.	THER. 60°	62°	64°	66°	68°	70°	72°	74°	76°	78°	80°	82°	84°
29·5	983	978	973	968	962	957	952	947	941	936	930	924	919
29·6	986	981	976	971	966	960	955	950	944	939	933	927	922
29·7	990	985	980	974	969	964	959	953	948	942	937	931	925
29·8	993	988	983	978	972	967	962	957	951	946	940	934	928
29·9	997	991	986	981	976	970	265	960	954	949	943	937	932
30·0	1000	995	990	985	979	974	968	963	958	952	946	941	935
30·1	1003	998	993	988	983	977	972	966	961	955	950	944	938
30·2	1007	1002	996	991	886	980	975	970	964	959	953	947	941
30·3	1010	1005	1000	995	989	984	978	973	968	962	956	950	945
30·4	1014	1008	1003	998	993	987	982	976	971	965	959	954	948
30·5	1017	1012	1006	1001	996	990	985	980	974	969	963	957	951
30·6	1020	1015	1010	1005	999	994	988	983	977	972	966	960	954
30·7	1024	1018	1013	1008	1003	997	992	986	981	975	969	963	957
30·8	1027	1022	1017	1011	1006	1000	995	990	984	978	972	967	961
30·9	1031	1025	1020	1015	1009	1004	998	993	987	982	976	970	964
31·0	1034	1029	1023	1018	1013	1007	1002	996	991	985	979	973	967

ADVERTISEMENTS.

WEST'S

GAS IMPROVEMENT COMPANY,

LIMITED,

Are now prepared to Supply and Erect their Patented Machinery for

CHARGING

AND

DRAWING GAS-RETORTS,

And to enter into arrangements with Gas Companies for its use upon moderate terms of Royalty.

The charging and drawing of retorts by machinery, actuated directly or indirectly by steam-power, has never proved commercially successful, and the projectors of such systems have never furnished reliable evidence of the cost of working and the results obtained. West's System assists and reduces manual labour. It has stood the test of time and severe trial. The Company are prepared to submit irrefutable proofs that by working on this system the following advantages are obtained:—

MORE GAS PER TON OF COAL,

MORE GAS PER RETORT,

GREAT SAVING IN COST OF LABOUR.

From which facts RESULT

LESS COAL TO BE CARBONIZED,

FEWER RETORTS IN ACTION,

FEWER MEN FOR THE WORK TO BE DONE.

The System may be seen in full operation at the Maidstone Gas Works on application to the Manager.

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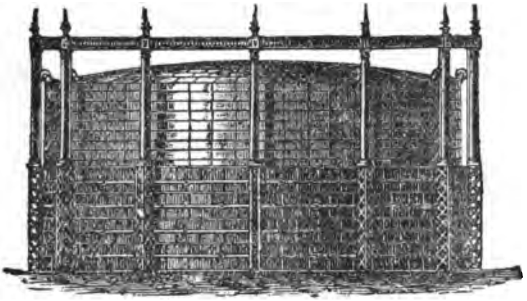

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IMPROVED GAS VALVES,

WITH WROUGHT-IRON PINIONS.

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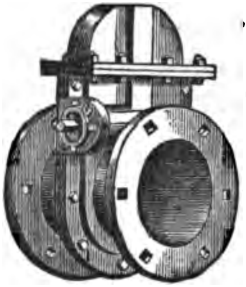

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J. BEALE'S NEW PATENT GAS EXHAUSTERS,
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VALVES FOR AMMONIACAL LIQUOR,
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Plans furnished, and the Apparatus supplied and erected for the manufacture of Sulphate of Ammonia.

Agent for Baldwin Latham's Patent Sewer Ventilators.

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PATENT "STANDARD"
WASHER & SCRUBBER.

This Washer and Scrubber has been used for nearly two years on a large scale at the Works of "The Gas Light and Coke Company," Bromley-by-Bow, and at Pancras Station; also at the Gas Works of the Corporation of Leeds.

The Special Merits of this Washer are as follow:

It is a very effective Condenser, so that it is not absolutely necessary to reduce the temperature of the Gas to 60°, or thereabouts, to make the Washer effective.

The distribution of the liquor is made with unerring regularity.

It occupies a very small space, so that it can be, at little expense, effectually protected from extreme changes of the weather.

The considerable expense of Coke or Wood, or other Scrubbing Material, is entirely saved, and the great nuisance and cost of from time to time replacing the Scrubbing Material is avoided.

By the revolution of the discs the quantity of water carried up by them, and tending continuously to fall, exposes a very large amount of fresh wetted surface in contact with the gas.

It is particularly adapted for Gas Works where Sulphate of Ammonia is manufactured.

It is much cheaper than any other Scrubber that will do the same amount of work effectually.

It is the only Washer suitable for purifying Gas from all its impurities by solution.

It works with a minimum of pressure.

It takes out every trace of Ammonia from the Gas in once traversing the machine.

It requires very little outlay for foundations.

The undermentioned Engineers have given Testimonials as to the thorough efficiency of the "Standard" Washer and Scrubber, and its power to remove the whole of the Ammonia from Coal Gas.

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JOHN CLARK, Esq., " "
HENRY WOODALL, Esq., Corporation Gas Works, Leeds.

For further Particulars and Testimonials apply to

MESSRS. KIRKHAM & HERSEY,
Consulting Engineers,
21, Abingdon Street, London, S.W.

SEE NEXT PAGE.]

Kirkham, Hulett & Chandler's Standard Gas Washer and Scrubber.

The following Table shows the results of the working of one of these Washers lately erected, to purify 60,000 feet of gas per hour, at the Pancras Station of "The Gas Light and Coke Company":—

1879.	Nos. of the Divisions and strength of liquor in each.										Water used per ton of Coals.	Gas purified per hour, Cubic feet.	Ammonia on outlet.	Temperature.			Pressures.		Revolutions per minute.
	1	2	3	4	5	6	7	8	9	10				Inlet.	Outlet.	Atmosphere.	Inlet, inches.	Outlet, inches.	
	oz.	oz.	oz.	oz.	oz.	oz.	oz.	oz.	oz.	oz.									
Jan. 1	8⅓	6⅔	5	3⅓	2⅓	1½	⅔	⅕	0	0	10 gals.	52,000	Nil.	77°	73°	48°	24	23	7½
2	8⅔	7	6	4⅓	3¼	2⅓	1⅓	⅔	⅓	0	10 ,,	57,000	Nil.	73°	66°	32°	21¾	20½	4
3	9½	8	6	3⅔	3	2⅓	1½	⅔	⅓	0	10 ,,	60,000	Nil.	75°	68°	40°	23½	22	4
4	9⅓	7⅔	6¼	4¼	3¼	2¼	1⅓	⅔	¼	0	10 ,,	65,000	Nil.	74°	68°	33°	24	22½	5
5	9½	7	6	4	3	2⅓	1½	1	⅓	0	10 ,,	34,000	Nil.	77°	68°	35°	14½	14	5
6	9½	7½	6⅓	4¼	3	2¼	1½	1	¼	0	10 ,,	63,000	Nil.	72°	66°	27°	21	22½	4½
7	11	9	7	5⅓	3⅔	3	1⅔	1⅓	½	0	10 ,,	59,000	Nil.	74°	66°	31°	25	23½	5
8	9½	7½	6	4½	3	2	1	½	¼	0	10 ,,	78,000	Nil.	73°	61°	31°	28	26½	4½
9	11	9	7	5	3⅔	2½	1⅓	1	⅓	0	10 ,,	82,000	Nil.	74°	67°	33°	27½	25½	5
10	10⅔	8½	6⅔	5	3⅓	2½	1½	1	⅓	0	10 ,,	66,000	Nil.	76°	61°	28°	28¼	27	5
11	12½	10	7⅔	5⅔	4⅓	3⅓	1⅔	1¼	½	0	10 ,,	61,000	Nil.	73°	64°	27°	26½	25¼	5
12	11	8⅔	6⅔	...	...	...	1¼	⅔	⅓	0	10 ,,	39,000	Nil.	74°	64°	27°	26¾	25½	5
13	13	10⅔	8¼	6	4⅔	3⅓	2	1½	½	0	10 ,,	78,000	Nil.	73°	65°	42°	28	26	5

(Signed) JNO. CLARK, *Engineer.*

For further particulars and testimonials address,

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SEE OPPOSITE PAGE.]

LIVESEY'S PATENT WASHER

Effects Complete Contact, which, in this apparatus, is produced

BY PASSING THE GAS in a FINELY-DIVIDED STATE through the WASHING LIQUID,
instead of merely over a wetted surface,
as in a scrubber.

The gas is twice broken up into small bubbles, by passing through finely perforated iron plates. The pressure does not exceed 3 inches.

It removes the whole of the Tar from the Gas, and nearly the whole of the Ammonia.

It strengthens the weak liquor, and causes it to take up a great quantity of Sulph. Hydrogen and Carbonic Acid.

It works uniformly without trouble, and the holes in the perforated plates neither become larger nor choked with Tar.

For Sizes and Prices see opposite page.

Washers of this kind have been fixed at the following Gas-Works :—South Metropolitan (4 years in use), Phœnix, Crystal Palace District, Coventry, Salford, Maidstone, Staleybridge, Rochester, Silvertown,
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⁂ These Washers are made in sizes, to pass from 100,000 per 24 hours and upwards.

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SIZES AND PRICES—LIVESEY'S PATENT WASHER.

To pass in 24 hours cubic feet.	100,000	250,000	500,000	750,000	1,000,000	1,500,000	2,000,000	3,000,000	And for each additional million,
Length	4 ft. 0 in.	4 ft. 0 in.	5 ft. 0 in.	6 ft. 0 in.	7 ft. 6 in.	7 ft. 6 in.	7 ft. 6 in.	7 ft. 6 in.	
Width	1 ,, 4 ,,	2 ,, 6 ,,	4 ,, 0 ,,	5 ,, 0 ,,	5 ,, 0 ,,	7 ,, 6 ,,	10 ,, 0 ,,	15 ,, 0 ,,	
Height.........	2 ,, 6 ,,	2 ,, 6 ,,	3 ,, 0 ,,	3 ,, 0 ,,	3 ,, 6 ,,	3 ,, 6 ,,	3 ,, 6 ,,	3 ,, 6 ,,	
Prices.........	£25	£40	£60	£80	£100	£145	£175	£240	£70

SEE OPPOSITE PAGE

FOR

NAMES OF AUTHORISED MAKERS.

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BY
OXIDE OF IRON.

GAS PURIFICATION & CHEMICAL CO., LIMITED,
Palmerston Buildings, Old Broad Street, London, E.C.
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ENGINEERS and MANUFACTURERS of

Gas Meters

Of the most perfect construction, as supplied for many years to the

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WRIGHT & CO.'s DRY METERS

Are surpassed by those of no other Maker, and are more substantial than most Dry Meters.

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Have received the testimony of 25 years' extensive use, and their construction has been copied by many Meter Makers. They ensure accurate measurement by compensation, *i.e.*, by maintaining the water level at its proper height. Compensation in a Consumer's Meter is generally essential, and a meter is a "Compensator," whether the *compensation* be effected by *water* or by *gas*. That meter is the best *which works with the least friction*, which is *the least complex*, and may be *most readily cleaned or repaired* when needful. These conditions are satisfied with A. WRIGHT & CO.'s Wet Meters.

Lists on Application.

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The most perfect of all Governors for reducing
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Lists on Application.

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AS APPROVED BY THE
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Lists on Application.

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LISTS ON APPLICATION.

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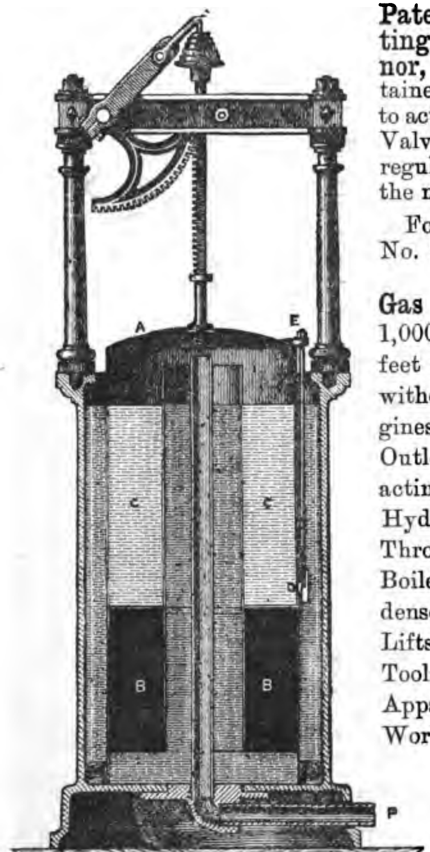

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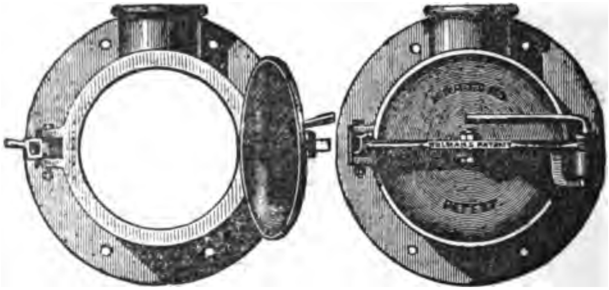

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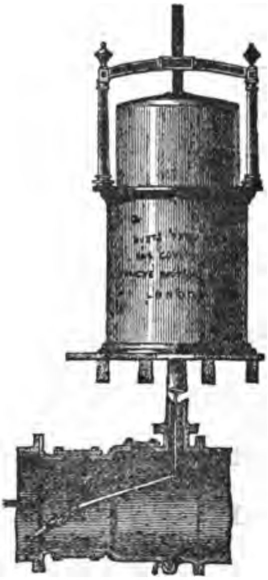

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